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Acadia Soundscape Analysis

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IQP:
Bar Harbor Soundscape Analysis

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Abstract: Soundscape research is becoming more important throughout the world as increases in population and technology have introduced damaging sounds into the environment. The objective of this project was to determine the baseline ambient sound levels within Acadia National Park in Maine and compare those levels to a similar 2005 study done by the Department of Transportation. This was accomplished by utilizing modern day technologies capable of recording decibel and frequency levels. Results revealed similar overall decibel averages when compared to those of 2005, but significantly larger percentile readings, possibly suggesting an increase in sound levels since 2005. Furthermore, this study's redesigned methodology left room for future expansion that the Park or future research teams can use.

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Future Work and Recommendations: Connor

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Executive Summary

In 2005 the Volpe Center assisted the National Parks Service (NPS) in conducting sound study research inside of the Acadia National Park (ANP) to determine the baseline ambient sound levels of the park to further understand the park's soundscape. The purpose of this study was to continue where the 2005 study left off by replicating the study as closely as possible as a means of comparison in order to do the following:

- Do a proof of concept on the accuracy and usability of newer methods and technologies
- Collect sound level data (both dBA and frequency based) to establish an updated ambient sound level baseline of the park
- Analyze the data and compare it to the 2005 data to look for trends and differences over time

This document summarizes the sound level study that was conducted inside of Acadia National Park located on Mount Desert Island in Maine. This study was conducted for seven weeks from June 17th to August 2nd of 2013 where seven days of recording were measured at five different sites located throughout Acadia. These five sites were selected from the original nine sites used in the 2005 study. This study selected only five sites due to the seven week time frame and some accessibility concerns. The original nine sites were selected based on a variety of factors. They were primarily selected through the determining of the "acoustic zones" present inside of Acadia using the National Land Cover Database (NLCD). These zones determined by the NPS and Volpe are described below:

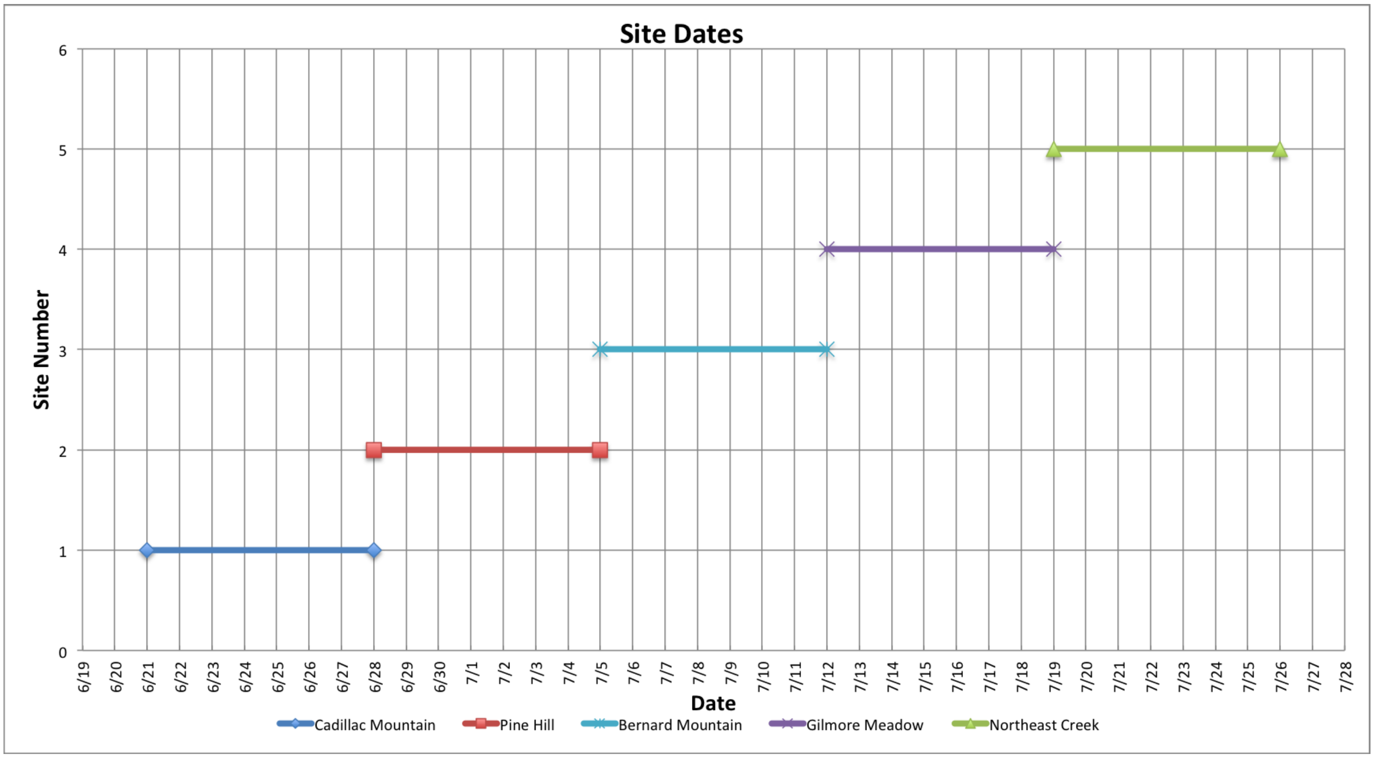
- Wetlands (Zone 1 – approximately 35 percent of the park) – includes the NLCD Woody and Emergent Wetlands and Water land cover categories;
- Evergreen Forest (Zone 2 – approximately 37 percent of the park) – includes the NLCD Evergreen Forest land cover category;
- Hardwood Forest (Zone 3 – approximately 7 percent of the park) – includes the NLCD Deciduous Forest land cover category;
- Mixed Forest (Zone 4 – approximately 17 percent of the park) – includes the NLCD Mixed Forest land cover category;
- Alpine (Zone 5 – approximately 1 percent of the park) – includes the NLCD Bare Rock/Sand/Clay and Transitional land cover categories;
- Shrubland (Zone 6 – approximately 1 percent of the park) – includes the NLCD Shrubland, Grasslands, Pasture/Hay, and Urban Grasses land cover categories; and
- Developed (Zone 7 – approximately 1 percent of the park) – includes the NLCD Developed land cover category.

Figure 1 shows a labeled map of the 5 recording sites of this project. Table 1 below it is a chart with each site's name and GPS coordinates. A timetable of when each site was recorded can be seen in graph 1.

Figure 1: Acoustic Locations

Site ID	Site Name	Latitude (decimal degrees)	Longitude (decimal degrees)
1	Bernard Mountain	44.30038	- 68.36605
2	Pine Hill	44.31484	- 68.39428
3	Northeast Creek	44.41876	- 68.31795
4	Gilmore Meadow	44.36273	- 68.27729
5	Cadillac Mountain	44.34983	- 68.22575

Table 1: GPS Coordinates of sites



Graph 1: Site Dates

To match the 2005 study as closely as possible, the same types of readings were recorded. These types of recordings are:

- Decibel Levels: Continuous, one second readings using A weighting
- 1/3 Octave Band: Continuous, one second readings of A weighed levels, split into 1/3 octave frequencies from 20 – 20,000 Hz
- Audio Recordings: Used for recording audio simultaneously with the acoustic data for cross-referencing. This is especially useful for identifying what the sound levels actually are (e.g. planes, birds, motorcycles, etc).

To obtain this data, the XL2 sound level meter by NTI Audio was chosen as it collects both the decibel levels and 1/3 octave band data needed. Furthermore it is portable and more affordable.

The audio data was recorded with a different device, which was the DR – 40 by Tascam Audio. It was capable of recording up to around 13 hours of audio on a battery charge which was enough to record from the afternoon into early morning. A picture of both the XL2 and DR – 40 is shown in figure 2 below.

Figure 2: NTI XL2 with M2230 Microphone (left) and Tascam DR-40 Recorder (right)

Table 2 contains a summary of all the acoustical sound level (dBA) data statistics for overall, daytime, and nighttime. These values were calculated for each of the recording sites. The rows of the table are organized by the site number. The upper five grouped columns of the table are explained below:

- *Site ID*: The site ID assigned to each site. See table 1 to see which site ID correlates to each site name
- *Overall*: The overall sound levels which takes into account all of the data from the entire 7 day period

- *Daytime:* The daytime sound levels - for this study between 7am and 7pm. Only data in this timeframe were used
- *Nighttime:* The nighttime sound levels – for this study between 7pm and 7am. Only data in this timeframe were used
- *Delta:* The difference between the daytime and nighttime sound level data

The three columns in each of the four grouped columns in table 2 are three kinds of statistics that were calculated for every group. The meaning of these three statistics is explained below:

- L_{Aeq}: This is the average of the data set, acquired by dividing the sum of the data points by the size of the data set
- L_{50}: This is the median of the data set, acquired by sorting the data points from lowest to highest and then selecting the midpoint
- L_{90}: This is the 90th percentile of the data set, acquired by sorting the data points from highest to lowest and then selecting the data point that marks the 90th percentile of the data set

Table 3, 4, and 5 show the L_{Aeq}, L_{90}, and L_{50} values, respectively, for each hour of the day at each site. The first column lists the site ID of each site, and every other column to the right is the corresponding hour of the day in the 24 hour format.

Due to an unfortunate power failure at Gilmore Meadow (site ID 4), no readings were collected at this site.

Site ID	Overall (entire 7 day period)			Daytime (7 AM - 7 PM)			Nighttime (7 PM - 7 AM)			Delta (Daytime - Nighttime)		
	L_{Aeq} (dBA)	L_{50} (dBA)	L_{90} (dBA)	L_{Aeq} (dBA)	L_{50} (dBA)	L_{90} (dBA)	L_{Aeq} (dBA)	L_{50} (dBA)	L_{90} (dBA)	L_{Aeq} (dBA)	L_{50} (dBA)	L_{90} (dBA)
1	37.7	35.2	27.6	36.5	34.5	28.6	39.1	36.3	26.7	-2.6	-1.8	1.9
2	35.2	33.8	28.2	35.5	34.0	29.9	34.9	33.4	27.4	0.6	0.6	2.5
3	30.0	28.9	26.6	30.1	29.2	37.0	30.1	28.5	26.4	0	0.7	3.6
4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	37.2	37.1	29.5	39.5	39.0	32.4	34.9	34.7	28.0	4.6	4.3	4.4

Table 2: Overall and Daytime VS. Nighttime Decibel Averages

Site ID	Hours of The Day																						
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	41.1	39.4	38.9	37.8	38	33.6	30.7	31.3	32.8	33.2	32.8	35.1	38.5	39.5	39.1	38.2	37.5	40.2	39.1	39.6	42.3	42.6	42.1	41.4
2	34.0	33.4	34.2	34.3	37.9	37.4	37.0	37.1	36.3	35.2	36.5	35.1	34.7	34.4	34.3	35.3	35.4	36.5	35.7	33.8	33.8	33.6	33.7	35.2
3	28.9	29.8	29.4	29.5	32.5	33.5	32.3	31.4	31.5	30.7	31.7	30.7	30.2	30.4	29.8	28.2	28.5	28.2	28.4	28.9	30.6	28.5	28.3	28.2
4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	32.3	30.8	30.7	32.0	36.2	36.8	38.2	41.0	41.1	41.4	41.5	41.6	38.1	39.7	38.0	38.0	38.3	37.1	36.6	36.3	38.2	36.8	36.3	34.9

Table 3: Hourly Decibel Readings For Each Site (L_{Aeq} dBA)

Site ID	Hours of The Day																						
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	26.6	25.9	25.7	26.0	28.9	27.5	26.9	27.5	27.9	28.9	28.3	28.4	29.7	29.2	29.2	29.0	29.0	28.8	29.5	29.5	30.2	29.5	28.3	28.0
2	34.0	29.9	31.0	30.5	38.8	37.2	35.7	35.6	35.1	34.2	34.5	33.5	33.9	33.6	33.0	34.1	34.9	34.1	33.1	31.9	32.1	32.1	32.8	34.0
3	26.3	26.3	26.3	26.3	27.1	27.5	27.6	27.6	27.1	27.5	28.0	28.0	27.4	27.7	27.5	27.0	26.9	26.6	26.5	26.6	26.5	26.5	26.5	26.3
4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	27.0	26.6	26.8	26.9	29.1	30.1	32.5	34.8	34.7	33.4	35.2	34.6	33.4	33.0	31.4	31.7	32.1	30.7	30.1	30.1	31.8	31.4	30.9	29.5

Table 4: Hourly Decibel Readings For Each Site (L_{90} dBA)

Site ID	Hours of The Day																						
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	38.8	34.8	32.1	29.5	36.3	32.2	29.3	30.0	32.0	32.5	32.2	33.7	37.8	39.4	37.5	35.2	35.1	40.4	38.3	38.7	42.3	42.6	40.6	38.0
2	27.0	26.9	26.6	26.6	29.0	29.5	29.7	30.0	30.6	29.7	30.0	30.0	30.2	30.0	29.6	30.3	30.2	29.4	28.9	28.4	28.4	28.2	28.4	27.8
3	27.9	30.4	29.1	28.3	31.5	32.0	30.3	30.1	30.3	30.2	30.8	30.0	29.9	29.6	29.0	28.6	28.2	27.5	27.6	27.8	27.9	27.2	27.3	27.1
4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	31.6	30.0	29.5	30.4	36.1	36.6	38.3	40.7	40.9	41.0	41.7	41.3	37.8	38.1	38.2	38.6	38.7	37.5	36.7	36.3	38.9	36.5	36.3	34.8

Table 5: Hourly Decibel Readings For Each Site (L_{50} dBA)

To compare the results from this study to the results of the 2005 study, percent differences were calculated for overall and daytime statistics as shown in table 6. Percentages over 10% are highlighted in yellow. These percent differences gave insight both into how accurate this study was, and shows that sound levels have potentially changed since 2005. The L_{Aeq} percent differences for both overall and daytime values were very low. They were as low at 0% and as high as 15.5%. This means that the newly used equipment and redesigned methodology was fairly scientifically accurate. The L_{50} and L_{90} percent differences were much higher, however. There are two hypotheses for why this might be. The first is that not enough data was collected, and further data would be needed to get the same results. The 2005 study recorded for usually twenty-five days at each site, where this study used a seven day recording window. The other hypothesis is that sound levels in Acadia National Park have changed since the 2005 study. Higher L_{50} and L_{90} values are a good metric for this since they are not skewed by outliers as heavily as averages.

Site ID	Overall (entire 7 day period)			Daytime (7 AM - 7 PM)		
	L_{Aeq} (%error)	L_{50} (%error)	L_{90} (%error)	L_{Aeq} (%error)	L_{50} (%error)	L_{90} (%error)
1	0%	21.8%	39.4%	7.1%	15.4%	23.8%
2	0.3%	20.4%	101.4%	1.1%	16.0%	29.4%
3	15.5%	24.6%	106.2%	14.7%	12.3%	46.7%
4	N/A	N/A	N/A	N/A	N/A	N/A
5	11.4 %	4.5%	10.1%	9.8%	2.9%	0%

Table 6: Percent Differences

Chapter 1: Introduction

Sound can be a beautiful thing, especially when arrays of different pitches and tones are harmoniously mixed together as in a natural environment. However, with an increase in population and technology, an abundance of artificially created sounds from humans and machinery is blended into the collection. This unwanted and damaging noise affects the sound makeup of a land area. Such a sound makeup is known as a soundscape. This project aims to help Acadia National Park in Maine to maintain its soundscape by fighting the addition of synthetic noise into the environment. This was be done by monitoring the Park's sound levels in different areas of the park.

Soundscapes in national parks are a concern because sound pollution compromises them. Sound pollution drowns out the natural sounds of the environment and distracts visitors who seek peaceful and natural aural experiences. Visitors end up finding these parks noisier than they hoped. Furthermore, sound pollution forces wildlife species to alter their behaviors. These include communication, ability to hear predators, find food, and reproduce (NPS 101). These alterations can have major impacts on vegetation and entire habitats.

Therefore, baseline sound levels have been recorded and analyzed at Acadia National Park. These levels, when compared with subsequent measurements, can determine how sound has changed over time. To this end, in 2005 the Department of Transportation (DOT) researched time and frequency based sound characteristics inside of Acadia National Park to establish such baselines. In addition, DOT identified the sources that contributed to the soundscapes within Acadia (Lee, MacDonald et al. 99).

Since that study, there has been little follow up research. Today's soundscape is not known. One possible reason for this hiatus in research and data collection is the cost associated with hiring personnel and the amount of effort required to gather such data. Many of these parks do not have the resources to efficiently gather audio data on their own.

Over time there have been improvements in technology and decreases in cost. For example, with the increase in mobile smart phone capability, there are now applications that can make recordings and analysis similar to those of more expensive equipment. Another technological improvement shows that abatement equipment can be placed inside parks to reduce noise pollution.

This project tested and utilized some of these technologies while also raising awareness of the importance of sound quality. Specifically, the team monitored ambient noise levels over time within the Park. This determined which parts of the Park are most impacted and why. With this information the team helped Acadia National Park enhance its soundscape and raise awareness about unwanted sounds. Research from this project provided a source for methodologies and equipment, and a data benchmark for future projects. This will allow all establishments, in addition to Acadia and other parks, to assess and analyze their soundscapes, while also educating the public.

Chapter 2: Background

Nature preservation is a national problem that has become more significant over the years. It is why many national parks strive to protect nature and the environment. Acadia National Park in Maine is one example of many parks that exists to preserve nature. One of the aspects of nature that Acadia National Park is currently attempting to better understand is sound. Sound is an important part of nature that contributes to the overall quality of Acadia National Park.

It is important to understand the impact ambient sound makes on nature and its surroundings. This section (2.1) will examine sound preservation within US National Parks and then specifically Acadia National Park. Next, this project will explain the social implications of sound preservation and the motivations for preserving natural sounds (2.2). Finally, a description of the technical term for the sound makeup in a natural environment, soundscape, will be explored (2.3).

2.1 Sound Preservation

The amount of artificial and man-made sounds has been rising. This rise directly results from increased population, urbanization, and technology such as airplanes, cars, and other transportation and machinery. In large cities there are many loud noises heard twenty-four hours a day, seven days a week. Worldwide, the amount of sounds being heard and created is increasing.

As technology advances, many daily activities and other essential products become habits. Many appliances like garbage disposals, dishwashers, clothes washers and dryers, refrigerators, furnaces and many more are all considered necessary. However, all of these result in introducing more noise into the environment (Goines and Hagler 99). In addition, increased aircraft traffic in the United States contributes to increased sound levels (Suter 101). What most people do not realize are the aesthetic, social, and medical ramifications that increased exposure to greater levels of sounds can have on humans. The level of sound will continue to rise as the population grows, man-made noise increases, and a lack of education remains.

Soundscape preservation is a problem throughout national parks in the US. As specialist in natural resources, Wes Henry put it, "A lot of parks look like they did 200 years ago, but they don't sound like they did" (David Foster 98). Over the years, these parks have been making big steps towards preserving natural sounds to alleviate this problem. With an average of over 300 million yearly visitors to these Natural Parks, and an expected increase to 367 million by 2020 (NPS 101), these parks must adapt new technologies to combat the unwanted man-made noises from their visitors.

A large source of this noise comes from automobiles, “a highly mobile and varied source of noise” (Goines and Hagler 99). Traffic congestion can cause serious damage to "fragile natural and cultural resources, especially when vehicles are parked in undesignated areas” (NPS 101). Parks have begun implementing custom public “green” buses that operate more quietly than the standard bus to reduce the noise generated by vehicles on the roads. For example, Zion National Park’s bus service in Utah accomplished the noise reduction equivalent of erecting a 12 to 15 foot tall highway noise barrier, with an estimated cost of $1,000,000 per mile, for significantly less money and significantly less negative visual obstruction (Roof, Kim et al. 101). Another example is the Island Explorer Shuttle Bus that is provided by Acadia National Park for visitors during the summer season.

Although this is a great first step, more work still needs to be done. Not every park has an effective public bus service, and even if every park did, that still would not reduce sound levels enough. In spite of a lot of research, the problem remains unsolved (Warren, Katti et al. 101).

2.1.1 Sound Preservation in Acadia National Park

Sound plays a very important role in many national parks around the U.S. It gives each park its own culture and significance, and distinguishes it from other parks. Acadia National Park is devoted to protect natural sounds not only for the park visitors, but also for its wildlife. With more than 47,000 acres and with the number of visitors increasing, sound preservation becomes more and more challenging. Acadia National Park is the home for many different species and natural wonders that give pleasant listening experiences. As a result, Acadia National Park is employing outsourced consultants to help maintain the beautiful sounds for which it is known (Region 100).

One of the several ways Acadia National Park protects its environment is through measuring the ambient sound level of the Park. This can be used to keep track of how sound is changing over time. The measuring of ambient sound levels was completed in 2005 with the help of the U.S. Department of Transportation (DOT). They catalogued the variety of sounds in different locations and recorded the frequencies that characterize the sound makeup. This information helped create a baseline for sound levels that is used by Acadia National Park to determine what areas most need improvement (Lee, MacDonald et al. 99).

Another way that Acadia National Park has helped reduce noise in the park is by implementing a system of public transportation that reduces the number of vehicles. A free bus service not only protects the environment but also makes it easier for visitors to travel from one location to another. The Island Explorer Shuttle Bus System promotes a better park experience by offering eight different routes that include the most attractive sights of the park. Seeking to better the stay of its visitors and the environment, Acadia National Park has made a step towards its goals to reduce sound with these buses and routes.

2.2 Social Implications

The effects of unhealthy sounds can damage humans and the environment alike. This has increased concern in social awareness groups. Noiseoff, Noise Free America, and Noise Pollution Clearinghouse are examples of nonprofit organizations taking the initiative to raise concern of these adverse effects of noise pollution (NoiseOFF 100). People visit national parks for a "sense of place, cultural significance, [interacting] with landscape perceptions", values that can be attributed to the natural sounds in the environment (Dumyahn and Pijanowski 98). It is important for the public to realize how critical sound is to the natural environment as a whole.

2.2.1 Motivational Factors

The reason behind the extra attention and care for sound preservation lays in twofold - human health and environment quality. Large amounts of research have been done to elaborate both, and the results are conclusive.

Elevated noise has received considerable attention from researchers who are interested in human well-being (Warren, Katti et al. 101). Noise stresses people, causing detrimental effects on human health (Passchier-Vermeer and Passchier 100), interfering with complex task performance, modifying social behavior, and causing annoyance (Stansfeld and Matheson 101). The visitors of national parks are trying to "escape the fast pace of daily life," to relax and de-stress (NPS 101). When they are subjected to copious amounts of unwanted noise, this quickly becomes impossible.

In addition, sound is the main means by which many animals communicate. Many species are physiologically constrained to produce specific sounding calls, while many bird and insect species are capable of altering their signals to escape unwanted noise (Warren, Katti et al. 101). By going in and invading these natural communications with man-made sounds, some of these species are forced to adapt to a new noisy environment, "potentially impairing their ability to communicate" (Rabin and Greene 100).

Noise can also hinder reproduction within species. Research shows noise might "limit the distributions of particular animal species that are intolerant of noise or negatively affect reproductive success in species forced to breed in noisy environments" (Warren, Katti et al. 101). Species can be forced to move away from noisy environments they cannot live in. During this process, mates might lose each other as they spread out, damaging entire habitats. This is illustrated by birds, as lower densities and diversity of bird species are found in proximity to roadways (Reijnen and Foppen 101).

These are just a few of the many damaging consequences of unwanted noise. These consequences are what drive national parks and other groups interested in the preservation of nature to take steps to reduce this damage.

2.3 Soundscape

It is important to make the distinction between noise pollution and a soundscape. While noise pollution is considered a form of air pollution and a threat to health and well-being (Goines and Hagler 99), a soundscape can be simply defined as “the collection of sounds that emanate from landscapes” (Pijanowski, Villanueva-Rivera et al. 100). The overall layout or composition of a soundscape is highly dependent on location. For example, the “living sounds of vocalizing and stridulating animals and the non-biological sounds of running water and rustling wind emanate from natural landscapes” (Pijanowski 100). Urban landscapes, in contrast, are dominated by man-made sounds such as “machines, sirens, and the friction of tires rotating on pavement” (Barber, Crooks et al. 98).

Ever since founder of the modern day environmental movement Rachel Carson discovered the link between sound and environmental health, there has been “little universally appreciated measure of a coupled natural-human system” (Liu, Dietz et al. 99). Although the ecological significance of all sounds emanating from a landscape is still a developing theory, sound artist such as R. Murray Schafer strongly agrees that a balanced soundscape could be a solution for many ecological problems (Helmut Kallmann 99).

Therefore, the US National Park Service (NPS) has been developing the methods, processes, and skills required for over seventeen years to effectively manage the soundscapes of the National Parks (Miller 100). With this, protection of soundscapes has received growing attention from managers and policy makers as a result of an increased understanding of its role in overall ecosystem health and visitor enjoyment (NPS 101). Advanced computing systems and digital processing have enabled researchers to analyze soundscapes all over the world in order to determine the significance of sound in a natural landscape. These technologies were used in this study to collect an acoustic record in order to analyze the soundscape of Acadia National Park.

2.3.1 Soundscape Analysis

To analyze a complete soundscape, various kinds of sound need to be recorded and processed for analysis. The characteristics of sound that need to be considered are amplitude, pitch, and weighting. Each of these were also collected and analyzed in the 2005 study.

A general description of amplitude is the level of loudness. Measuring the loudness is important because it will determine the overall sound level of a soundscape. For example, the amplitude of the sound waves emitted from a crying child is greater than that of a small chirping bird. A measure of the amplitude of a sound wave is given by the relative measure of sound pressure levels (SPL) with respect to a reference level (Eliopoulos, Drosopoulos et al. 99). The unit associated with amplitude is the decibel, abbreviated as dB (*Refer to Appendix A for the standard* *dB equation and reference level).* Figure 3 below gives a reference scale showing how loud specific sounds are.

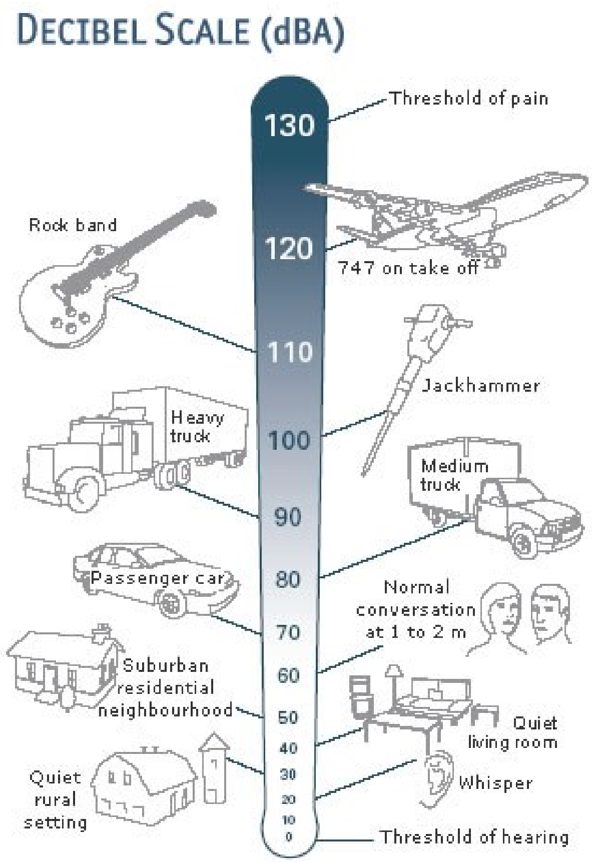


Figure 3: Decibel Scale (dBA)

Another key feature of such an analysis is pitch or how high or low the sound is. Pitch is measured through frequency. Frequency analysis is important in a soundscape because it can explain the sources of sounds. For example, an airplane and a bird have very distinct and different frequency profiles. A sound wave's frequency can be defined by the number of oscillations for every unit of time. Frequency is measured in the unit called the hertz, abbreviated as Hz. Moreover, timbre can be used to further explore frequency components of a sound. It defines the quality of a sound, and can distinguish between different qualities of sound such as voices, wind, and musical instruments.

The manner by which humans perceive sound is interesting in that certain frequencies sound louder than others. The middle range of frequencies that is within the range of human hearing tends to be amplified, while extreme high and low frequencies sound quieter. This has been scientifically proven through experiments. The experiments yield what is now known as Fletcher-Munson curves that show how the human ear perceives different ranges of frequencies. Figure 4 below shows a standard Fletcher-Munson curve.

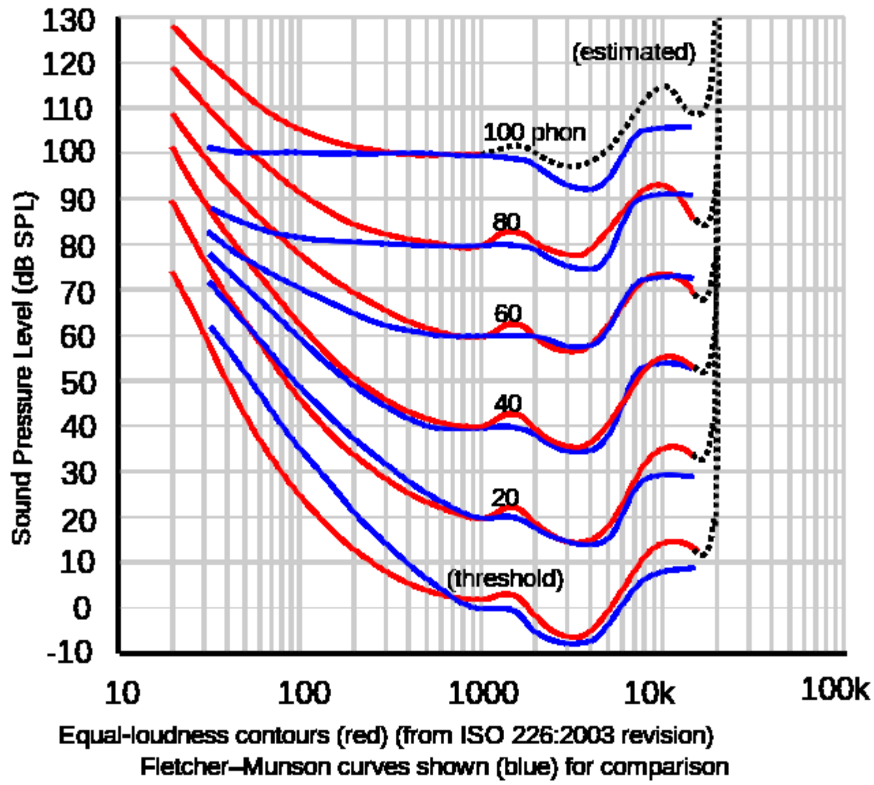


Figure 4: Fletcher-Munson Curves

When conducting ambient sound level recordings, this bias should be taken into consideration. Although there are many different weighting scales to measure this hearing phenomenon, this study will be using the A - weighted scale. The team chose this because the A-weighting network de-emphasizes the high (63,000 Hz and above) and low (below 1,000 Hz) frequencies, and emphasizes the frequencies between 1,000 Hz and 63,000 Hz. This range will most closely simulate the relative response of human hearing (Lee, MacDonald et al. 99) (*Refer to Appendix B for a standard A-weighted response curve).*

Chapter 3: Methodology

More than two million people visit Acadia National Park each year to experience its natural beauty and to escape from the fast pace of everyday life. As a result, this project established a baseline of the sound levels within the park and compared the data to the report completed in 2005 by the DOT. The objective was to replicate the results of the 2005 study, and with this comparison determine whether the soundscape is changing. This project required the seven weeks between June 17th and August 2nd where the following objectives were accomplished:

- Select sites to collect data
- Measure ambient sound levels in selected sites
- Analyze and compare data with the 2005 study

A visual representation of the methodology used is shown in Figure 5.

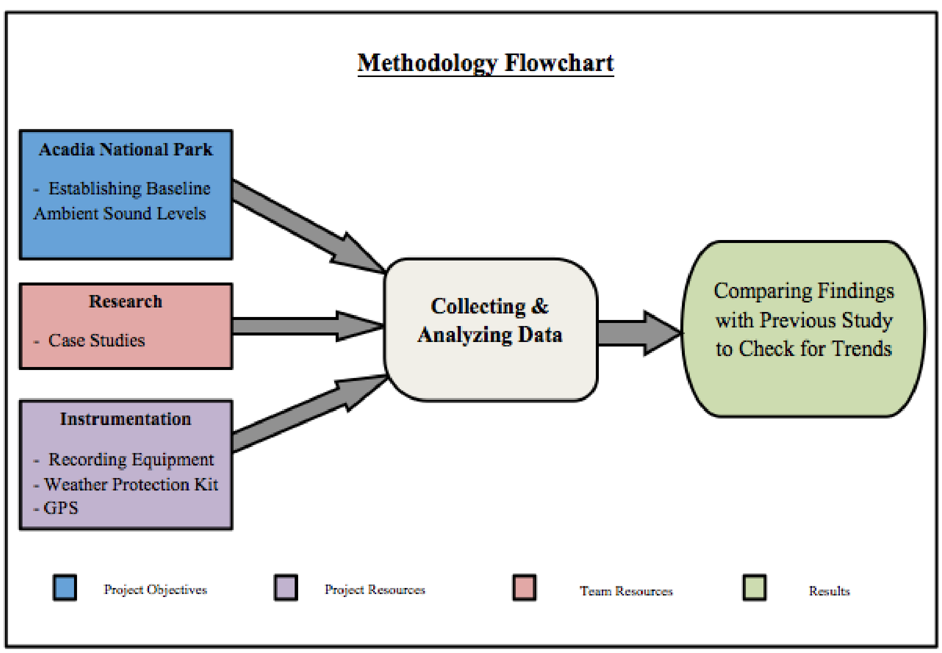


Figure 5: Methodology Flowchart

3.1 Assessing The Acoustical Needs of Acedia

The Acadia National Park has a mandate to reduce noise pollution. "In 1972, the Noise Control Act required the federal government to establish and enforce noise controls in work and other places, including national parks" (David Foster 98). National Parks have been trying to oppose noise encroachment from "artificial" sources like automobiles, air traffic and human settlement growth. In an effort to combat the problem, the National Park Service has been consulting with various firms and groups to formulate an approach to this problem. This group was one of the teams Acadia National Park asked to conduct analysis and provide recommendations regarding soundscape.

One of Acadia's concerns regarding sound preservation is the noise produced by the air tours flying by Mount Desert Island. To respond, the project determined several objectives. First, the project collected frequency and decibel readings twenty-four hours a day for one week at five locations. The established baseline was compared with the 2005 study to test the validity of this study with considerations to external factors. The established baseline also allows future studies conducted within Acadia to have a comparison point for their studies. With such a baseline, trends can be determined. Such trends can demonstrate what park policy is needed and how well it works. From this point, additional steps can then be taken to regulate the sound inside the park.

Additionally, the project provided the park with actual recordings of ambient sound that could be used to further explain the decibel readings. They could also be used to identify the frequency readings and assign them to what they represent such as motorcycles, automobiles, airplanes, birds, and people.

Another objective sought to partially replicate the plan for recording sound levels in Acadia in 2005. However, it is not possible to completely replicate the testing completed at all of the sites in the 2005 report due to having had a limit of only seven weeks inside the park and access to just one complete set of equipment. The previous study was replicated as best as could be done by following the timeline that is shown in Figure 6:

TASK	WEEK							
	Pre-arrival	6/17	6/24	7/1	7/8	7/15	7/22	7/29
Determine & Test Equipment	X							
Select Sites	X							
Collect Data		X	X	X	X	X	X	
Analyze & Compare Data			X	X	X	X	X	
Present Findings							X	
Finalize Report							X	X

Figure 6: Timeline

3.2 Ethics

For every study to be successful, a certain ethical code must be kept. For example, it is extremely important to maintain the confidentiality of all the human subjects that will be involved in this project.

The code of ethics was observed during this study. This ensured that setups were safe and did not harm visitors. Furthermore, the team captured voices of the park's visitors in the recordings. This might cause an ethical issue because they did not consent to be recorded. Filtering the recordings and eliminating the unwanted voices avoided this issue.

3.3 Site Selection

Acadia National Park extends to more than 47,000 acres (Park Statistics 98). This means that a sound sample taken from one location does not represent the entirety of Acadia's soundscape. To appropriately assess the sound levels inside of the park, data had to be collected from multiple locations. In determining these locations, the same criteria from the 2005 study were used. These criteria considered the following:

1. Various environmental effects on sounds
2. Proximity to roads and flight paths
3. Popularity of location/amount of human traffic

In addition to the criteria used by the 2005 study, two more had to be used specifically for this study in finalizing the locations that would be recorded. These additional criteria are:

1. Time Considerations
2. Accessibility to Locations

3.3.1 Environmental Effects

One of the most important factors that went into site selection in the 2005 report was the effect that different environments have on sound. The environmental factors that were taken into consideration are vegetation and land type, and climate because these all affect the behavior of sound in the environment differently. For example, in forested areas sound will reflect from or be attenuated by trees and leaves. Open and unobstructed areas have the opposite effect, since sound travels much farther without attenuation. A location's climate is also important to consider. Locations with higher elevations tend to experience higher wind speeds, thereby increasing sound levels (Lee, MacDonald et al. 99). Furthermore, temperature and humidity play important roles in both the speed at which sound travels and the distance it can be heard at (Lee, MacDonald et al. 99).

These exact environmental effects were examined and discussed thoroughly in a meeting during august 2005 by Volpe and the NPS, and took into account various categories from the National Land Cover Database (NLCD). They determined that Acadia is composed of seven "acoustic zones", which they originally described as below:

- Wetlands (Zone 1 – approximately 35 percent of the park) – includes the NLCD Woody and Emergent Wetlands and Water land cover categories;
- Evergreen Forest (Zone 2 – approximately 37 percent of the park) – includes the NLCD Evergreen Forest land cover category;
- Hardwood Forest (Zone 3 – approximately 7 percent of the park) – includes the NLCD Deciduous Forest land cover category;

- Mixed Forest (Zone 4 – approximately 17 percent of the park) – includes the NLCD Mixed Forest land cover category;
- Alpine (Zone 5 – approximately 1 percent of the park) – includes the NLCD Bare Rock/Sand/Clay and Transitional land cover categories;
- Shrubland (Zone 6 – approximately 1 percent of the park) – includes the NLCD Shrubland, Grasslands, Pasture/Hay, and Urban Grasses land cover categories; and
- Developed (Zone 7 – approximately 1 percent of the park) – includes the NLCD Developed land cover category.

3.3.2 Proximity to Roads and Air Traffic

The main reason the 2005 study was conducted was because of increasing air traffic, and the newly trending air concessions. Therefore the activity levels of each location, in terms of aircraft, vehicles, and other machinery, were considered. Locations of the park that are under these routes experience high amounts of artificial noise from the aircraft. The map in Figure 7 shows popular flight paths around Acadia National Park. The 2005 team selected areas that lie under or near these routes to determine the impact of the air traffic.

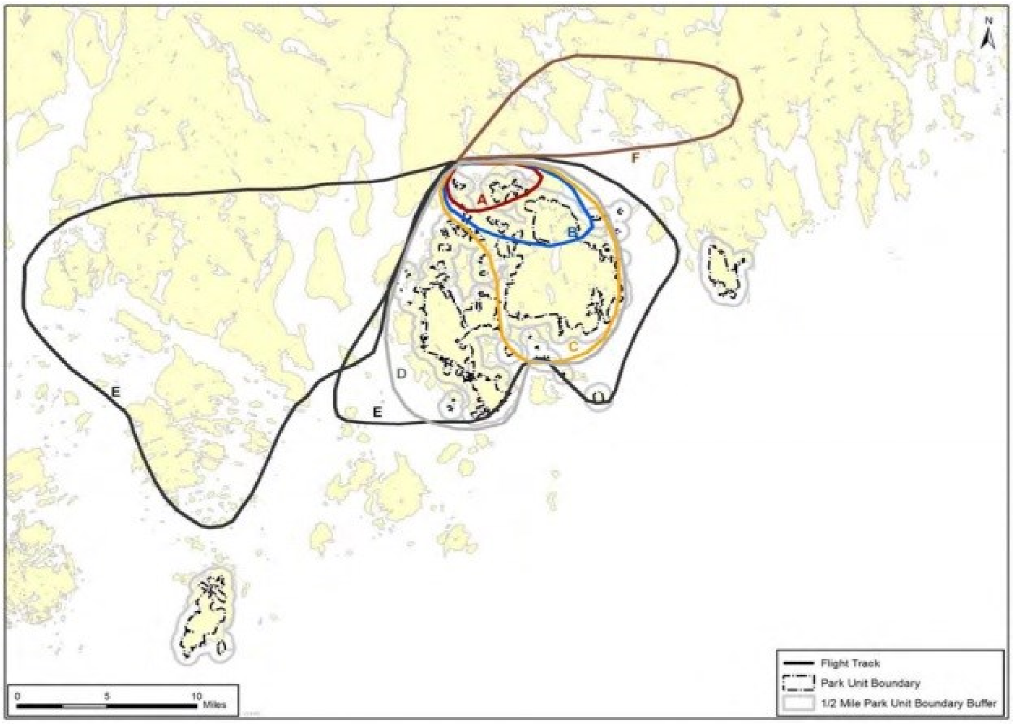


Figure 7: Flight paths of air tours in and around Acadia National Park (Lee 12)

3.3.3 Popularity and Human Traffic

Human traffic was also taken into account during site selection in the 2005 report. During the summer months Acadia can become crowded with large concentrations of people on certain trails and locations inside the park. Increased traffic means increased sound, so locations of high popularity like Cadillac Mountain must be measured. Each location was given a category of visitor use from high to medium to low.

3.3.4 Time Considerations

A difference between this study and the 2005 study is the duration of the project. With a seven-week time frame and one set of equipment, certain considerations had to be made regarding locations and durations of recordings. The number of locations that need to be analyzed is critical to ensure that the soundscape represents the whole park. The 2005 research study took measurements at nine locations, usually for twenty-five days each (they had a few "experimental sites" that were recorded at for only a day or two as well).

With this limitation, two choices were available. First, the project could consider recording at only one location. This might be preferable because "Acoustic literature shows that a minimum 25-day measurement period limits the measurement uncertainty of ambient data collected in various national parks to less than three decibels" (NPS 101). This would achieve maximum accuracy and guarantee the location is properly represented.

The other option was to record at multiple locations for shorter time periods. While this might not be preferable, it means that more locations could be measured. More locations will provide a better representation of Acadia National Park as a whole. However, using multiple locations for shorter periods would serve more as a proof of concept for the new equipment.

3.3.5 Accessibility

Lastly, accessibility to the original locations was considered. There are a few locations the 2005 study recorded that were not on the island. Furthermore, they were off limits to park visitors. Although it was possible to collect sound data from these locations the information was not as relevant to this study. Moreover, it would have been difficult to easily access these locations with the heavy equipment. Therefore, this project focused on locations on the island that are open to the public.

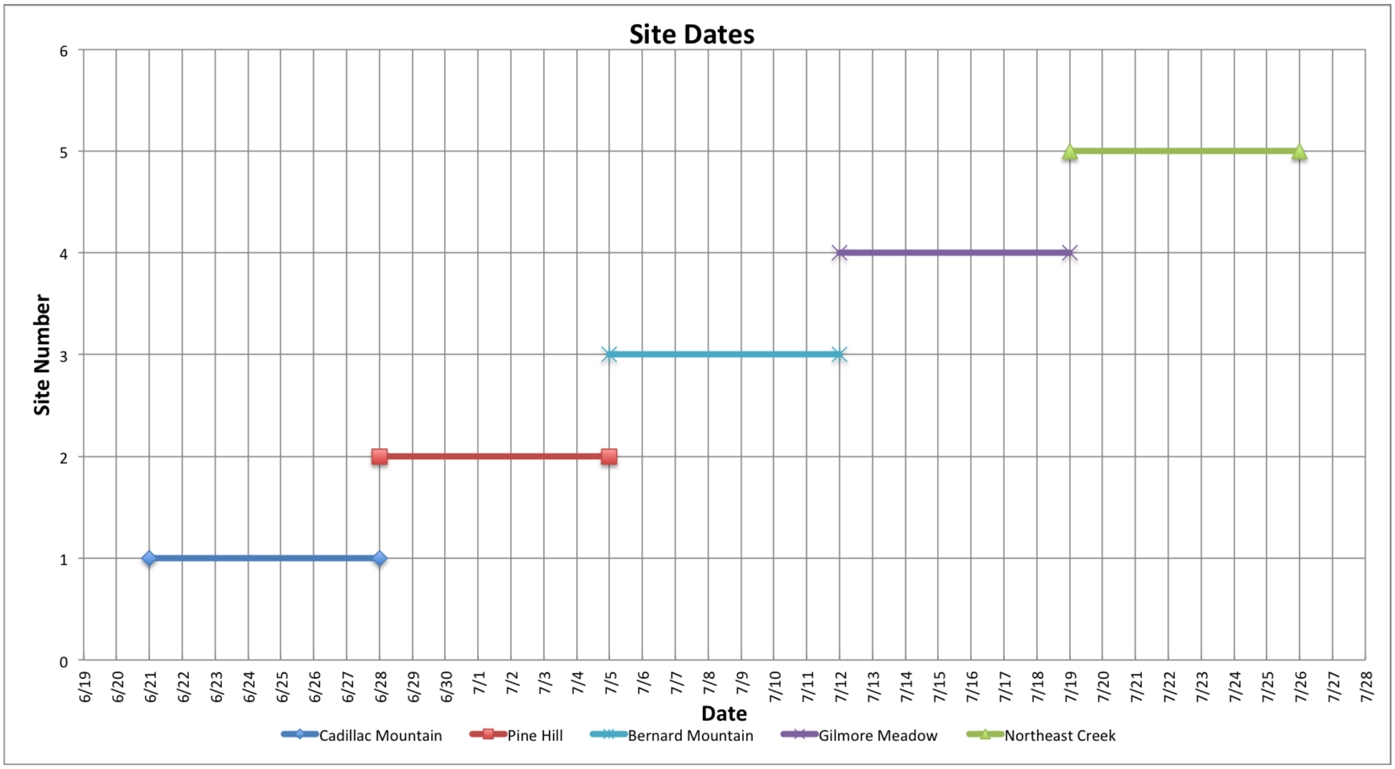
3.3.6 Final Selected Sites

With everything discussed above taken into consideration, five of the original nine locations from the 2005 study were used. These sites are shown on a map in Figure 8, and listed in Table 7 below. A time chart of when each site was recorded is also shown in Graph 2.

Figure 8: Acoustical Locations

Site ID	Site Name	Latitude (decimal degrees)	Longitude (decimal degrees)
1	Bernard Mountain	44.30038	- 68.36605
2	Pine Hill	44.31484	- 68.39428
3	Northeast Creek	44.41876	- 68.31795
4	Gilmore Meadow	44.36273	- 68.27729
5	Cadillac Mountain	44.34983	- 68.22575

Table 7: GPS coordinates of acoustic locations



Graph 2: Site Dates

3.4 Instrumentation

Refer to Appendix C for complete step-by-step setup procedure used with instrumentation.

At each of these locations, various kinds of sound were recorded and processed for analysis through specialized equipment and software. These sounds were then used to analyze the baseline sound levels within the park.

Acoustic equipment was selected in accordance with the following criteria:

1. Total cost under $2000
2. Compact and easy to setup
3. Modular and easy to utilize by future teams
4. Single audio analyzer capable of collecting both frequency and decibel readings
5. The ability to collect high quality data
6. The ability to read ambient sound amplitudes or decibels (dB)
7. The ability to analyze 1/3 octave band frequencies
8. The ability to perform A-scale weighting
9. The ability to log data with custom sample time intervals
10. Weather protected

3.4.1 Sound Meter

After taking the criteria into consideration, the team selected the XL2 Sound Analyzer with the M4260 Microphone from NTI Audio, as show in Figure 9**:**

Figure 9: NTI XLR with M2230 Microphone (2013)

For approximately $1,700 the XL2 Sound Analyzer, using the M2230 microphone, is perfect for a complete soundscape analysis *(Refer to Appendix D for data sheets and references).*

One key feature of such a soundscape analysis is amplitude. The amplitude levels determined can be compared to previous years' levels in order to determine the change over time and to predict future levels. The microphone the team used was the M2230 from NTI audio. The team picked the M2230 because it has a good decibel range from 0 – 140 dB *(Refer to Appendix D for complete specs).*

By measuring ambient sound levels in Acadia, the team tracked decibels over time. Furthermore, measurement allowed us to determine which parts of the island are most affected by sound and therefore require the most attention. In order to determine a trend, the team took the average decibel reading per day and compared that to the 2005 averages.

Another key feature of such an analysis is pitch or how high or low the sound is. Frequency analysis is important in a soundscape because it can explain the sources of sounds. For example, an airplane and a bird have very distinct and different frequency profiles. By using the M2230 microphone, the team was able to collect frequencies in the range from 12.5 Hz to 20,000 Hz *(Refer to Appendix D for complete specs).*

By monitoring the frequencies present in Acadia, the team could determine which ranges are most present and why, and what impacts they have on the surrounding environment. There are many methods to collect frequency, however the degree of accuracy required determines what method must be chosen. For this study's needs, the team collected discrete ranges of frequencies in a frequency range between 12.5 Hz and 20,000 Hz. These ranges are called ⅓ octave bands (*Refer to Appendix B for a table of the standard 1/3 octave band ranges, and refer to Appendix A for the equations that govern them).* Similar to the ambient dB readings, the team took the average Hz reading of each frequency, and compared that to the averages found in the 2005 report.

The manner by which humans perceive sound is interesting in that certain frequencies sound louder than others. The middle range of frequencies that is within the range of human hearing tends to be amplified, while extreme high and low frequencies sound quieter. When conducting ambient sound level recordings, this bias should be taken into consideration. Although there are many different weighting scales to measure this hearing phenomenon, this study will be using the A - weighted scale. The team chose this because the A-weighting network de-emphasizes the high (63,000 Hz and above) and low (below 1,000 Hz) frequencies, and emphasizes the frequencies between 1,000 Hz and 63,000 Hz. This range will most closely simulate the relative response of human hearing (Lee, MacDonald et al. 99) (*Refer to Appendix B for a standard A-weighted response curve).*

To get the most accurate results for this research, sound samples must take place over long extents of time. This leads to vast numbers of data that is too many to sort manually. Thus, data logging was critical to the study, and the chosen equipment had to have this capability. Data logging refers to the ability to not only collect data but to associate that data with dates and times. Each data point can then be saved for future reference. The XL2 Sound Analyzer has built in data logging and allowed us to change the rate at which the team wanted to collect or sample data. The DOT used a sample rate of 1 second. This is also what this study used. This limited the data for easier analyzing, yet not to the extent where the accuracy of the results were diminished too far.

3.4.2 Digital Audio Recorder

Although getting amplitude and frequency readings is helpful, it would be far more significant if the team can identify what sounds are being heard. To do this, the team occasionally used a digital audio recorder. A picture of the DR – 40 digital recorder from Tascam is shown below in Figure 10.

Figure 10: Tascam DR-40 Recorder

With this audio, the team had the ability to play it back at specific times and cross-reference it with the decibel and frequency readings from the XL2. Using specialized audio software called Ableton Live gave the ability to eliminate unwanted noise and pick out the relevant sounds more clearly. Identifying what sounds are occurring gave a better idea of the soundscape at each site. *(Refer to Appendix D for data sheets and specs on the Tascam).*

3.4.3 Weather Protection

Since the XL2 was left outside for lengthy periods of time the team needed to ensure the protection of the equipment. The equipment was subjected to rain, wind, and other elements that can cause damage or inaccurate data. To ensure that the equipment did not break a specialized weather protection kit was used. This kit includes a Pelican© waterproof case and an Auray WSF-2216-WP water resistant foam windscreen. The case protected the XL2 from rain. The windscreen filtered out extremely loud wind sounds to reduce biasing in the data. Furthermore, the windscreen protected the microphone against rain and other sources of moisture *(Refer to Appendix D for references on the box and windscreen)*. This kit is shown below in Figure 11:

Figure 11: Pelican Waterproof case (left) and Auray water resistant windscreen (right)

3.4.4 Batteries

The last piece the team had to consider was battery life. Although the team could have gone out and changed batteries as needed, this would have been a tedious and expensive process. The three main options were to swap out rechargeable XL2 batteries when needed, use rechargeable

AA batteries, or use a long lasting car battery. With cost and life efficiency both factored into the decision, the team ultimately choose to purchase two 12 volt car batteries, as shown in Figure 12 *(Refer to Appendix D for details):*

Figure 12: 12 volt car battery (Jazzy 2013)

3.5 Data

In the end of this project, the team will end up with other 3,000,000 data points. With all of this data, special steps had to be taken in order to efficiently process this data. Although the team could copy and paste each set of data into the necessary programs to graph it, this becomes tedious and wasteful. To make the process more efficient, specialized software was written.

3.5.1 Using Automation To Process Data

The XL2 analyzer records both the 1/3 octave frequencies and the average decibel readings at a sampling rate of 1 second. It conveniently writes this data to a nicely formatted text file. But while it is easy to read, there are approximately 86,400 data points collected every twenty-four hours. This means the data starts to become unmanageable by hand very quickly.

There are pieces of software that make this collection process much easier like Microsoft Excel or MatLab from National Instruments. There are, however, other problems such as cutting out bad data due to equipment maintenance, and picking only specific columns of data that the team need from the outputted text file. To combat these problems and make the data processing move smoothly and quickly, small pieces of software were written to help automate most of the process. There are two main pieces of software that are used; one that is run daily after the data is collected from the site, and another that is run once all the data has been collected per site.

Daily Data Collection:

Once the data has been successfully copied over from the equipment and the team has left the site, that days' worth of data is processed through a piece of software written in the Python programming language. This Python 'script' takes in two text file logs: decibels and 1/3 octave frequency levels. Once the script has these two logs, it proceeds to go through both files and create excel readable files. The decibel file has a column for time stamps, and a second one for the decibel level at that point in time. The frequency file has two columns as well. One is the 1/3 octave frequencies, and the other has the average decibels over the entire duration for each frequency.

With the data extracted and exported into Excel, graphs can easily be plotted and looked at with a few mouse clicks. This greatly reduces the time and stress it would have taken to graph the data that was collected, and therefore allows the team to visualize and analyze the data much sooner.

Weekly Site Data Processing:

After an entire site's worth of data has been collected, further and more intensive processing can be computed. To compare this study's findings with the 2005 report, overall averages and day vs. night averages were calculated and observed. In order to do this quickly and easily, a second Python script was written to crunch all of the numbers that were needed.

In addition, it is important to seamlessly stitch together all of the data the team had pulled from the XL2 everyday for the seven days. Furthermore it must cut out the times that the team was on site for maintenance because this data is skewed. After the data stitching and cutting, those averages were computed by running the script, which are printed to the screen.

Refer to Appendix E for all python code.

3.5.2 Statistical Tools For Graphing Data

In the 2005 study, three different statistical strategies were used to analyze the data. Since this project aims to replicate the work done in the previous study, the same three tools were used in analyzing the data obtained. They are as follows:

- L_{Aeq}: This is the average of the data set, acquired by dividing the sum of the data points by the size of the data set.

- L_{50}: This is the median of the data set, acquired by sorting the data points from lowest to highest and then selecting the midpoint.

- L_{90}: This is the 90th percentile of the data set, acquired by sorting the data points from highest to lowest and then selecting the data point that marks the 90th percentile of the data set.

Each of those tools has a different statistical purpose that it satisfies. The average is usually used when outliers, or extreme data points, are not present. It is also used when there is more interest in the data set as a whole than the individual points that make the data set.

The second tool is the median (L_{50}), and it is used when extreme data points are present in the data set. Unlike the average, the median provides a more accurate result when dealing with outliers since the outliers will not have a significant contribution to the median.

The third statistical tool is the 90th percentile denoted by (L_{90}). This tool represents a value in which 10 percent of the data lie below it and 90 percent of the data lie above it. This is particularly useful in this project because it shows that 90 percent of the time the noise level exceeded the value calculated in L_{90}, and only 10 percent of the time is below L_{90}. This value could easily determine how loud a particular site is when compared with the L_{50} and L_{Aeq} values of the same site.

Our project also utilized another statistical tool that is moving average. Since we collected many data points, it became difficult to visualize them as they are. Therefore a moving average was used to smooth the graphs and make them easier to interpret. This smoothing is done by going through each point of the original noisy data set, and creating a new data set. Every data point in the original set is replaced with the average of the next n data points in the new data set. The number seven for n was selected for this arbitrarily. Through trial and error it was determined to smooth the graphs most effectively.

3.5.3 Comparing Data

One of the most important resources available to us was the 2005 study. Once sound data was gathered from each site the team averaged all the numbers to establish a baseline reading for each site. By aggregating the data into hourly averages the team was able to compare this study's results with those of the 2005 study. Comparing the data showed a number of things:

1. The accuracy of results
2. Whether sound levels have decreased/increased

Determining the accuracy of the results determined the level of difference between this study's results and those of 2005. The results in the 2005 study were decibel averages and frequency averages for each site. Furthermore, daytime and nighttime decibel readings were compared. This was done to get a sense of how much planes and other vehicles impact the sound level within the park because air tours and other traffic usually occur during the daytime hours.

Also, the team cannot match the 2005 data, as sound levels have probably changed since then. Furthermore, it is possible that there were mistakes made with the 2005 data, rendering it a less than accurate baseline. To address these possible shortcomings two assumptions were made. First, any error in the 2005 data is not large enough to significantly impact results. This ensures that the team had an accurate baseline with which to compare this study's own data to. Secondly, the team assumed going into this project that their data should be very close to that of the 2005 data. To further this point, a small increase in their sound level data will be regarded as accurate, as sound levels have tended to increase over the years, generally speaking.

3.6 Recommendations

After acquiring all the desired data, the team was able to assist Acadia National Park in determining the current ambient noise level and offer recommendations. The recommendations were based on the instrumentations used and the methods performed to collect data as well as the cost, efficiency, and accuracy of this project compared to the 2005 study. Because noise pollution has to be monitored periodically, the recommendations were of value to Acadia National Park so that they can be used in future improvements.

Chapter 4: Results

In this chapter, the data is presented. This is broken down into five tables. The first table (Table 8), shows the overall decibel averages for each site in $L_{Aeq,}$ L_{50}, and L_{90}. Furthermore, this table also contains the daytime (7 AM to 7 PM) and nighttime (7 PM to 7 AM – highlighted in tan) decibel averages for each site. These averages are expressed in the same units as the overall averages. Lastly, this table has the delta, or difference, between the daytime and nighttime decibel readings. The second, third, and fourth tables (Tables 9 to 11) have the hourly decibel averages for each site. The first of these tables is in the units of L_{Aeq}, the second is in L_{90}, and the third is in $L_{50.}$

The last table (Table 12**)** has all of the frequency data collected for each site. Unlike the decibel readings, the frequency values are not averaged by daytime and nighttime, nor are they averaged hourly. Instead, an overall decibel reading at each site for each 1/3 octave band frequency is calculated.

These tables sum up all of the decibel and frequency readings obtained. These numbers will later be used in *Chapter 5: Discussion and Analysis*.

Due to a power failure at Gilmore Meadow, no data was collected at this site. Refer to Chapter 6 on how this can be avoided in future studies.

Site ID	Overall (entire 7 day period)			Daytime (7 AM - 7 PM)			Nighttime (7 PM - 7 AM)			Delta (Daytime - Nighttime)		
	L_{Aeq} (dBA)	L_{50} (dBA)	L_{90} (dBA)	L_{Aeq} (dBA)	L_{50} (dBA)	L_{90} (dBA)	L_{Aeq} (dBA)	L_{50} (dBA)	L_{90} (dBA)	L_{Aeq} (dBA)	L_{50} (dBA)	L_{90} (dBA)
1	37.7	35.2	27.6	36.5	34.5	28.6	39.1	36.3	26.7	-2.6	-1.8	1.9
2	35.2	33.8	28.2	35.5	34.0	29.9	34.9	33.4	27.4	0.6	0.6	2.5
3	30.0	28.9	26.6	30.1	29.2	27.0	30.1	28.5	26.4	0	0.7	0.6
4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	37.2	37.1	29.5	39.5	39.0	32.4	34.9	34.7	28.0	4.6	4.3	4.4

Table 8: Overall and Daytime VS. Nighttime Decibel Averages

Site ID	Hours of The Day																							
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	41.1	39.4	38.9	37.8	38	33.6	30.7	31.3	32.8	33.2	32.8	35.1	38.5	39.5	39.1	38.2	37.5	40.2	39.1	39.6	42.3	42.6	42.1	41.4
2	34.0	33.4	34.2	34.3	37.9	37.4	37.0	37.1	36.3	35.2	36.5	35.1	34.7	34.4	34.3	35.3	35.4	36.5	35.7	33.8	33.8	33.6	33.7	35.2
3	28.9	29.8	29.4	29.5	32.5	33.5	32.3	31.4	31.5	30.7	31.7	30.7	30.2	30.4	29.8	28.2	28.5	28.2	28.4	28.9	30.6	28.5	28.3	28.2
4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	32.3	30.8	30.7	32.0	36.2	36.8	38.2	41.0	41.1	41.4	41.5	41.6	38.1	39.7	38.0	38.0	38.3	37.1	36.6	36.3	38.2	36.8	36.3	34.9

Table 9: Hourly Decibel Readings For Each Site (L_{Aeq} dBA)

Site ID	Hours of The Day																							
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	26.6	25.9	25.7	26.0	28.9	27.5	26.9	27.5	27.9	28.9	28.3	28.4	29.7	29.2	29.2	29.0	29.0	28.8	29.5	29.5	30.2	29.5	28.3	28.0
2	34.0	29.9	31.0	30.5	38.8	37.2	35.7	35.6	35.1	34.2	34.5	33.5	33.9	33.6	33.0	34.1	34.9	34.1	33.1	31.9	32.1	32.1	32.8	34.0
3	26.3	26.3	26.3	26.3	27.1	27.5	27.6	27.6	27.1	27.5	28.0	28.0	27.4	27.7	27.5	27.0	26.9	26.6	26.5	26.6	26.5	26.5	26.5	26.3
4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	27.0	26.6	26.8	26.9	29.1	30.1	32.5	34.8	34.7	33.4	35.2	34.6	33.4	33.0	31.4	31.7	32.1	30.7	30.1	30.1	31.8	31.4	30.9	29.5

Table 10: Hourly Decibel Readings For Each Site (L_{90} dBA)

Site ID	Hours of The Day																							
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	38.8	34.8	32.1	29.5	36.3	32.2	29.3	30.0	32.0	32.5	32.2	33.7	37.8	39.4	37.5	35.2	35.1	40.4	38.3	38.7	42.3	42.6	40.6	38.0
2	27.0	26.9	26.6	26.6	29.0	29.5	29.7	30.0	30.6	29.7	30.0	30.0	30.2	30.0	29.6	30.3	30.2	29.4	28.9	28.4	28.4	28.2	28.4	27.8
3	27.9	30.4	29.1	28.3	31.5	32.0	30.3	30.1	30.3	30.2	30.8	30.0	29.9	29.6	29.0	28.6	28.2	27.5	27.6	27.8	27.9	27.2	27.3	27.1
4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	31.6	30.0	29.5	30.4	36.1	36.6	38.3	40.7	40.9	41.0	41.7	41.3	37.8	38.1	38.2	38.6	38.7	37.5	36.7	36.3	38.9	36.5	36.3	34.8

Table 11: Hourly Decibel Readings For Each Site (L_{50} dBA)

Frequency (Hz)	Average Sound Level For Each Site (dBA)				
	1	2	3	4	5
12.5	-0.8	-29.6	-31.7	N/A	-25.5
16	4.2	-23.2	-25.4	N/A	-17.8
20	8.5	-17.5	-22.0	N/A	-11.3
25	12.5	-11.2	-17.9	N/A	-6.3
31	16.3	-5.0	-12.9	N/A	-1.5
40	18.6	-0.9	-9.1	N/A	2.9
50	20.3	3.1	-9.4	N/A	7.4
63	22.5	5.4	-1.7	N/A	11.5
80	23	6.4	1.6	N/A	13.0
100	23.5	6.6	4.3	N/A	12.7
125	23.1	7.3	5.4	N/A	12.3
160	22.5	9.1	5.9	N/A	11.6
200	22.4	11.1	7.0	N/A	12.4
250	21.6	13.0	9.0	N/A	14.3
315	21.1	15.7	10.8	N/A	17.8
400	21.1	18.0	12.7	N/A	21.0
500	21.5	20.1	13.9	N/A	23.6
630	22	21.6	15.2	N/A	25.8
800	22.9	22.6	16.5	N/A	27.7
1000	22.8	22.8	16.6	N/A	27.9
1250	22.7	22.5	17.2	N/A	26.7
1600	22.3	22.7	18.0	N/A	24.7
2000	21.6	22.6	18.3	N/A	22.2
2500	21.2	22.7	18.5	N/A	20.9
3150	21.2	23.2	18.9	N/A	21.2
4000	21.1	23.7	18.8	N/A	21.0
5000	20.3	22.3	18.2	N/A	20.1
6300	18.5	20.8	17.1	N/A	19.0
8000	17.7	20.5	16.2	N/A	18.1
10000	16.3	17.0	14.5	N/A	16.6
12500	13.6	14.9	12.5	N/A	15.5
16000	10.6	11.9	9.8	N/A	13.6
20000	7.6	8.7	6.9	N/A	10.3

Table 12: Frequency Profile For Each Site

Chapter 5: Discussion and Analysis

In this chapter the results from the previous chapter are used for five reasons:

1. Compare to 2005 data
2. Graphing and visualizing
3. Finding trends
4. Understanding soundscape of each site

In section 5.1, the data was compared to the data presented in the 2005 study. To do this, the level or percent difference was calculated between the decibel and frequency averages. This gives a good representation as to whether or not the findings are accurate.

In section 5.2, each site is individually analyzed. This breakdown of sites covers points 2 to 4 listed above. Graphs of each sites' daily decibel readings are explored and annotated for trends. This helps better understand the sound makeup at each site.

Appendix F contains annotated graphs that show specific manmade sounds that the team found to be intrusive upon the natural soundscape of each site. These sounds were determined by going out onto site and making observation logs and recording audio using the Tascam. After the data was collected, the observation logs and recordings were cross-referenced with the decibel readings. It should be noted that the chosen sounds were not the only intrusive sounds observed. They were, rather, a few of the many that were arguably the most conclusive. Each graph is titled with the site, followed by the units used, and lastly the date and time the sound was heard. Below each graph is a caption that says what the sound is.

Lastly, Appendix G contains overall 1/3 octave band frequency profiles for each site.

5.1 Comparison to 2005 Data

In order to compare the results to the 2005 data, a mathematical method must be used. The chosen method used is called percent difference. Percent difference finds the difference between a measured value and an accepted value to compare with. This difference is represented in a percent from 0% (measured value equal to accepted value) to any percent value above 0%. The higher the percent difference is the greater the difference between the measured and accepted values are. Typically, a good percent difference is less than 10%. The formula for percent difference is given below in equation 1:

$$Perecent\ Difference = \frac{|your\ result - accepted\ value|}{accepted\ value}\ x\ 100$$

Equation 1: Percent Difference Formula

It was decided that the most significant results from this study were those shown in Table 8**.** Although the hourly averages are helpful, the overall and daytime and nighttime averages are more substantial in the grand scheme of the project, and therefor will be used to compare data to. All percent errors can be found in Table 13 below. *It should be noted that all percent errors above 10% are highlighted in yellow*.

Site ID	Overall (entire 7 day period)			Daytime (7 AM - 7 PM)		
	L_{Aeq} (%error)	L_{50} (%error)	L_{90} (%error)	L_{Aeq} (%error)	L_{50} (%error)	L_{90} (%error)
1	0%	21.8%	39.4%	7.1%	15.4%	23.8%
2	0.3%	20.4%	101.4%	1.1%	16.0%	29.4%
3	15.5%	24.6%	106.2%	14.7%	12.3%	46.7%
4	N/A	N/A	N/A	N/A	N/A	N/A
5	11.4 %	4.5%	10.1%	9.8%	2.9%	0%

Table 13: Percent Errors

The percent differences in the above table range from 0% to 106.2%. In the following sections various explanations for these differences are investigated. It is important to note that nothing discussed should be taken as fact or being conclusive, and are made for the sake of discussion. This project only collected seven days of recording for each site and therefore does not meet the NPS minimum standard of twenty-five days of recording used in the 2005 study. It is possible that any extreme differences are from this lack of twenty-five days of recordings. Accuracy as far as averages and properly representing the soundscape could be questionable. However, this does not mean the data collected is inaccurate or insignificant. Rather, this means there are two hypotheses for differences in data:

1. Not enough data has been collected to fully represent the soundscape
2. The soundscape has changed since the previous 2005 report

5.1.1 Similar L_{Aeq} Statistics

By comparing data sets for each site, many interesting trends were found in comparison to the 2005 data. The most interesting and noteworthy comparison is between both overall L_{Aeq} values. As shown in Table 13, the percent differences in L_{Aeq} values at every site are all below 15.5%, and as low as 0% at the top of Cadillac. This is a substantial finding, considering it has been 8 years since the previous study, and the overall averages are relatively unchanged. What this means is that in these 8 years, the average levels of sound have been statistically similar. More importantly, it is now fairly conclusive that the equipment used for this project is at least as accurate as the equipment used in the previous 2005 study.

5.1.2 Differences in L_{50} and L_{90} Statistics

Not enough data

The simplest explanation for the discrepancies between the 2005 percentile data and this study's new data is not enough data was collected. Seven days of data is about 3/10 of the data used in 2005 and the amount required by the NPS to fully represent a soundscape. It is possible that having more data to average could result in hearing and recording lower noise levels similar to that in 2005. If this is the case, then the data collected cannot be viewed as completely representing the soundscape.

Speculation in changing soundscapes

While there is not enough conclusive evidence to prove the increase in sound levels, it is interesting to look at and consider. As discussed earlier, the median or L_{50} is used in acoustical studies as the better indicator for the middle sound in a soundscape, not the average. With this in mind, it is interesting to note that the differences in overall L_{50} have been around 20% and a difference of around 15% during daytime hours for most sites, with the exception of Northeast Creek which will be discussed later. With reasonably consistent differences in the median decibel values at each site, it is likely that this 15-20% difference is representative of an overall increase in sound levels on Mount Desert Island over the past 8 years.

Another useful indicator of increased sound levels is L_{90}. Since the L_{90} value is the dB value that happens at or above 90% of the time, it means that this should be a low number that would be close to the minimum data point recorded. For example, the overall L_{90} dBA value in the 2005 report was 19.8 dBA for Cadillac Mountain, meaning the lowest dBA value is likely under 19.8 dBA. It is interesting to note that the minimum data point in this report's overall data set was 25.4 dBA for Cadillac Mountain. With around a 5 dBA difference between this data set's lowest data point and the 2005 report's L_{90} value, it could imply that there was an increase in the overall sound levels at the top of Cadillac Mountain since 2005. Furthermore, similar increases and differences in the L_{90} statistics can be seen for other sites. Pine Hill and Bernard Mountain had a substantial increase of over 100% in L_{90}, making it twice as noisy as in 2005. This would further confirm the accuracy of this study's equipment and explain the high percent differences found for both the overall and daytime L_{50} and L_{90} values.

Another interesting trend noticed was the mostly consistent values for the L_{Aeq}, L_{50}, and L_{90} statistics per site. In comparison to the 2005 values, there is not much difference between these three values. At Bernard Mountain for example, there is only 3 dBA difference between the L_{Aeq} and L_{90} , for both the overall and daytime hours. Pine Hill had a similarly small difference with a 7 dBA difference between overall L_{Aeq} and L_{90}, and a 5 dBA difference in daytime hours. In the 2005 report, this was not the case. The 2005 data had much larger gaps between these values at Pine Hill, with a 21 dBA difference overall and a 12 dBA difference over the daytime hours. Similar large gaps are present at all of the recording sites in the 2005 report. This difference between LAeq and L_{90} means that today, the sound levels at each location are far more consistent. This trend can be visualized further in section 5.2, looking specifically at the dBA vs Time graphs. In 2005, the sound levels would have to be fluctuating very frequently at different parts of the day and week.

It should be noted once more that the above section is speculative, rather than conclusive.

5.1.3 Northeast Creek Outlier

The percent differences from the Northeast Creek data set was consistently low for all of the L_{Aeq}, L_{50}, and L_{90} values. The most notable difference to discover was the daytime L_{50} and L_{90} values, which were 2.9% and 0% respectively. The percent differences for these categories at the other locations were much higher than this, at 46.7% at the highest at Bernard Mountain. These low differences in percentiles from the 2005 study do not follow the trend that sounds could be increasing.

One explanation is that this location was placed about a half mile further away from the setup in 2005. After much struggle, an easy an efficient way to get to the exact GPS coordinates from 2005 was not found. Not being in the same exact location could explain why the trend that sound has increased over the years is not met at this site.

Another explanation is that location has not changed as much. This area of the park is on the north side of the island, and is not attached to the other areas of the park. While owned by the park, it is much less popular and not visited by many people. It is also very difficult to access.

With this in mind it makes sense that the levels are so close to the 2005 levels. This section of the park sees very little inconsistent human traffic, and likewise has probably not changed as much as other more visited sections of the park. In 2005 this site was also noted as the busiest in terms of air traffic, which is still true today as this site is located very close to where tour aircraft would take off.

5.1.4 Gilmore Meadow Unattainable Data

Due to some unpredictable and unavoidable events, only about one days worth of data was collected at the site Gilmore Meadow. Calculations were done on the data that was managed to be saved, however it was quickly determined that this data was useless. This is why there is no data present in the row for Gilmore Meadow. There was simply not enough data to adequately compare to the 2005 study and the calculated averages for this site meant nothing in the grand scheme of things. *Refer to Chapter 6 on future recommendations regarding this problem, and how it could be avoided or managed better in future work and projects.*

5.2 Site Breakdown

In this section, the sites are broken down in order to make it easy to present and explain the findings. The 5 sites are broken down into subsections 5.2.1 to 5.2.5 for convenience. Each site will have the following:

1. ID chart with the sites' essential information such as number, name, recording dates, and a description
2. Pictures of setup
3. Annotated decibel graphs with explanations

It should be noted that all decibel graphs shown do not use every single data point. When you graph every decibel reading, the graphs become unreadable. To make a good visual representation of the data, it was decided to use one data point every five minutes. From here, the rolling average was calculated from these data points.

Refer to Appendix G for overall 1/3 octave band frequency profiles for each site.

5.2.1 Cadillac Mountain Analysis

Site ID	1
Site Name	Cadillac Mountain
Measurement Dates	6/21/2013 - 6/28/2013
Latitude / Longitude (decimal degrees)	44.34983, -68.22575
Elevation (ft)	1492
Land Class	Barren
Site Description	Rocky, scarce trees, shrubs and grass
Access Notes	Drive to the top of Cadillac, hike about 100 feet into the south ridge trail, follow side trails on the left
Possible Sound Sources	Wind, humans, aircraft, motor vehicles, birds, insects

Table 14: Cadillac Mountain ID Chart


Figure 13: Cadillac Mountain Setup

The following graph (*Figure 14*) shows the rolling average of the decibel readings for all seven days at Cadillac Mountain. Each day is represented in a different color, and each color is explained in the legend to the right. Important trends are expressed with colored dashed lines and explained after the graph.

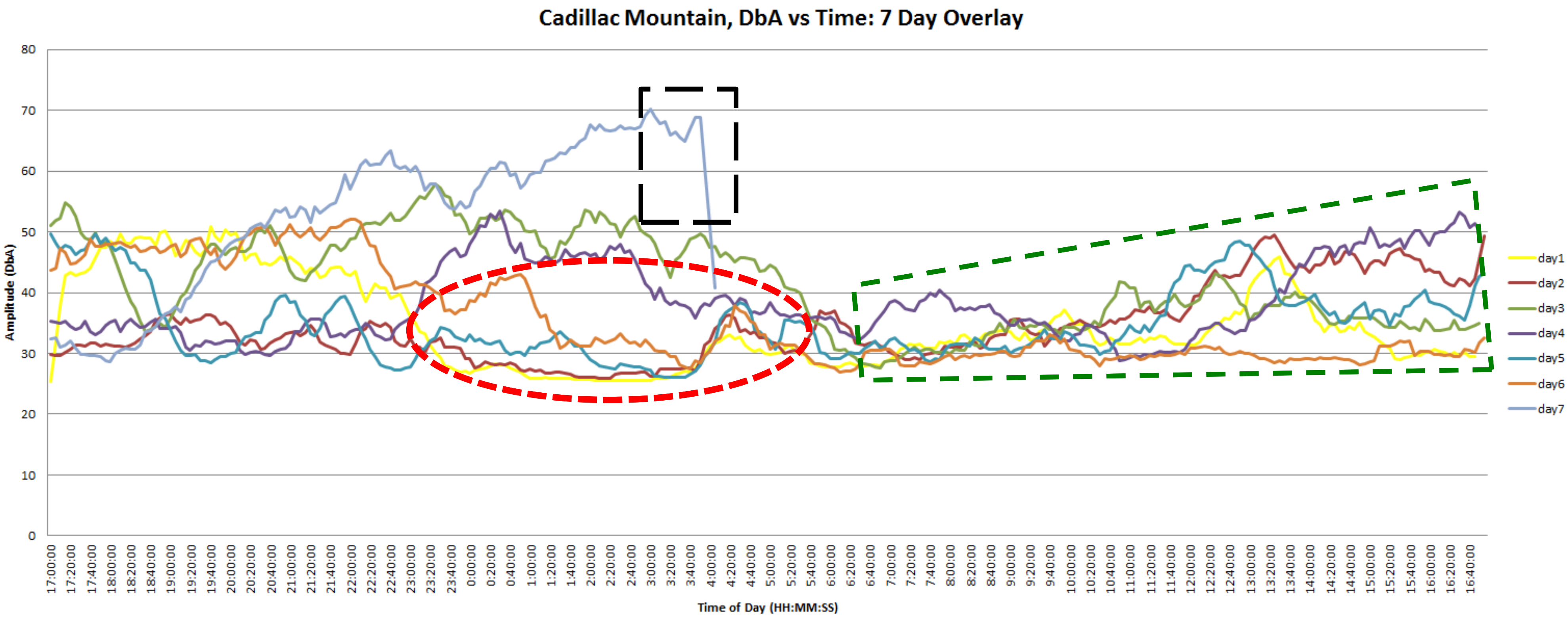


Figure 14: 7 Day Overlay of Decibel Readings at Cadillac Mountain

Equipment Failure: The power cable got pulled out of the XL2 due to extremely high wind speeds. Luckily the Xl2 was able to recover all data collected up to that point and save it. The recording ended soon after 4 AM. The loss of data was not significant since the team had collected data for seven days.

Bird Activity: For several days, especially days 1, 2, 5, and 6, there was a very distinct trend occurring between the hours of 22:00:00 and 4:40:00. Between 22:00:00 and about 3:40:00 those days' decibel readings were fairly flat. Then at around 3:40:00 the decibels peak until 4:40:00. To determine what this was, the team set up the Tascam digital audio recorder on site. The mp3 recording taken by the recorder was put into Ableton's audio software called Live to filter and listen to very clearly. It was confirmed that these readings were the result of birds going to sleep and then waking up around 3:40:00. This finding is probably one of the more substantial ones at Cadillac Mountain for a number of reasons.

Figure 15: Listening To The Birds Waking Up

First, it is a nice proof of concept that sound analysis can be used as a powerful tool to explore nature. Not only can it be used to determine sound levels, but it can also be used to determine animal activity. For example, light pollution is a known cause for birds waking up before sunrise. Recording decibel readings could show when birds wake up. This could then be related back to the levels of light pollution. Secondly, it is good evidence to show that the equipment is sensitive enough to pick up important but not necessarily loud changes in sound levels. This makes the setup more desirable as a way to monitor sound.

Human Traffic and Vehicles: Everyday from about 6:00:00 to 17:00:00 was about the same. After spending a few days on site making observation and traffic logs, it was concluded that this consistency was due to a constant flow of people and vehicles in and out of the top parking lot. There were no lengthy moments when people did not come in or out of the lot. Even though there were very few people that got close to the equipment, both human speech and miscellaneous automobile noise tended to travel decently well. Although automobile sound can be unpredictable, there was always a close to constant flow. This is why there were no large decibel spikes or other inconsistent findings. Sounds tended to increase throughout the afternoon simply because less people would go during the morning.

Refer to Appendix F for annotated graphs showing intrusive sounds upon Cadillac Mountain.

5.2.2 Pine Hill Analysis

Site ID	2
Site Name	Pine Hill
Measurement Dates	6/28/2013 - 7/5/2013
Latitude / Longitude (decimal degrees)	44.31484, -68.39428
Elevation (ft)	275
Land Class	Forested Upland
Site Description	Heavy forested with soft ground mixed with roots, moss, and rocks.
Access Notes	Drive to the top of the Long Pond Fire Road
Possible Sound Sources	Wind, distant humans, distant aircraft and motor vehicles, birds, insects

Table 15: Pine Hill ID Chart

Figure 16: Pine Hill Setup

The following graph (*Figure 17*) shows the rolling average of the decibel readings for all seven days at Pine Hill. Each day is represented in a different color, and each color is explained in the legend to the right. Important trends are expressed with colored dashed lines and explained after the graph.

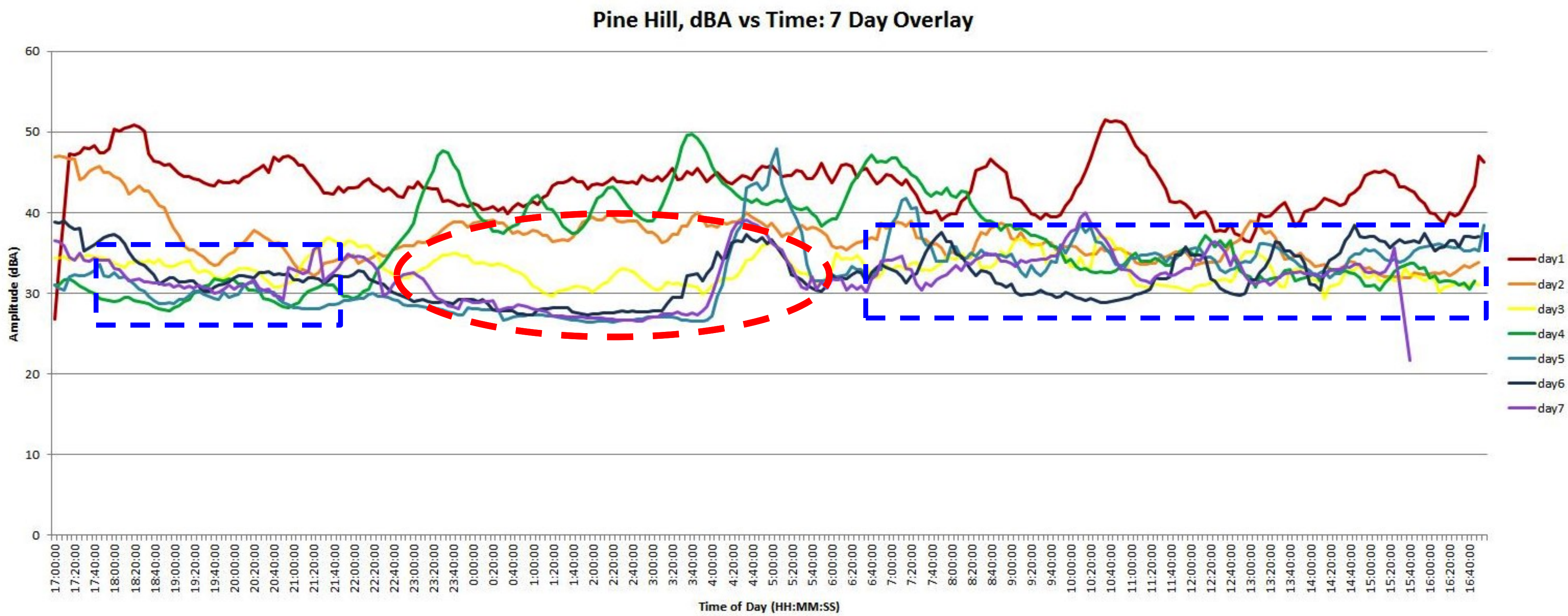


Figure 17: 7 Day Overlay of Decibel Readings at Pine Hill

Bird Activity: As with Cadillac there were several days, especially days 3, 5, 6, and 7 with a very distinct trend occurring between the hours of 22:00:00 to 4:40:00. Between 22:00:00 and about 3:40:00 those days' decibel readings were fairly flat. Then at around 3:40:00 the decibels peak until 4:40:00. To determine what this was, the team set up the Tascam digital audio recorder on site. It was confirmed that these readings were the result of birds going to sleep and then waking up around 3:40:00. This is pretty interesting because the times are near identical to those found at Cadillac Mountain. The team expected to find bird behavior, but not equal times. Since Cadillac Mountain is more open to the light in comparison to the highly wooded Pine Hill, the team thought the birds would wake up later at Pine Hill. This was not the case, however. This suggests that bird activity is very consistent throughout the park, regardless of the surrounding environment of each location.

General Ambient: Throughout most of the day, sound was fairly consistent. The rolling averages were for the most part flat and did not have high decibel spikes scattered throughout the hours. Days 1 and 4 deviate away from this trend slightly however. Although not confirmed, the team believes these days' data are due mostly to weather related sounds. It would make sense that Pine Hill is fairly consistent as human traffic in the area is *very* low. Cadillac, on the other hand, tended to be slightly more sporadic with increasing sound levels throughout the day due to vehicles and people. When listening to the Tascam's audio recording, it was clear that most of the decibel readings were attributed to birds, insects, and occasional wind.

Airplanes: Although it is not clear from the decibel graphs, it must be noted that the team determined a very high use of airplanes in the area of Pine Hill. This was determined by listening to the audio recording made from the Tascam as well as from the observation logs. This is a significant result for 2 reasons:

1. It confirms the use of illegal flights over the park
2. Despite the number of overhead flights, sound in the area was *not* greatly affected

Point number 2 is important to emphasize because the team cannot make concluding remarks regarding the intrusive nature of the airplanes' sound levels within the area of Pine Hill. The team looked into the specific times the airplanes could be heard, but the data did not show substantial increases in decibel levels for the most part. There was one plane in particular that was louder than normal and did impact the readings more substantially. The graph for this plane can be found in *Appendix F*. It should be noted that although there were many planes heard, they tended to be off in the distance. This could mean that other areas close to Pine Hill are being affected. This is speculation however and needs to be looked into further.

Refer to Appendix F for annotated graphs showing intrusive sounds upon Pine Hill.

5.2.3 Bernard Mountain Analysis

Site ID	3
Site Name	Bernard Mountain
Measurement Dates	7/5/2013 – 7/12/2013
Latitude / Longitude (decimal degrees)	44.30038, -68.36605
Elevation (ft)	363
Land Class	Upland Forest
Site Description	Forest with soft ground covered with rocks
Access Notes	0.5 mile hike up Sluiceway Trail
Possible Sound Sources	Wind, hikers, distant aircraft and motor vehicles, birds, insects

Table 16: Bernard Mountain Site ID Chart

Figure 18: Bernard Mountain Setup

The following graph (*figure 19*) shows the rolling average of the decibel readings for all seven days at Bernard Mountain. Each day is represented in a different color, and each color is explained in the legend to the right. Important trends are expressed with colored dashed lines and explained after the graph.

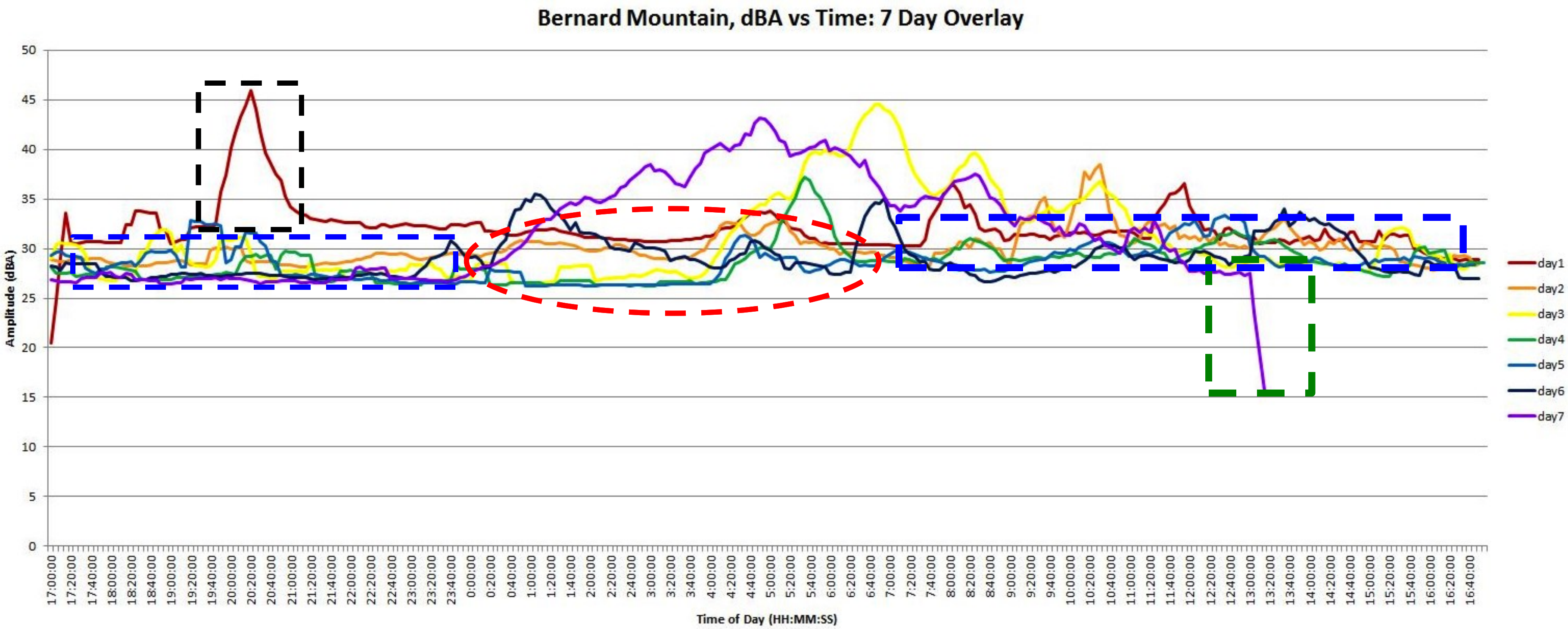


Figure 19: 7 Day Overlay of Decibel Readings at Bernard Mountain

***Possible* Bird Activity:** As with both Cadillac and Pine Hill there were several days, especially days 2, 3, 4, and 5 with a very distinct trend occurring between the hours of 22:00:00 to 4:40:00. Between 22:00:00 and about 3:40:00 those days' decibel readings were fairly flat. Then at around 3:40:00 the decibels peak until 4:40:00. Due to logistics and other technical issues, the team was unable to set up the Tascam digital recorder for this site. Therefore, it cannot be completely confirmed what this trend is. However, looking back at Cadillac and Pine Hill, it seems pretty conclusive that these readings were the result of birds going to sleep and then waking up around 3:40:00. If this is the case, it further suggests that bird activity is very consistent throughout the park, regardless of the surrounding environment of each location.

Unknown: Although these readings are due to an unknown source, it was deemed necessary to comment on it as it stands out from the rest of the readings. Due to the time of day (roughly 20:00:00) and duration it is unlikely to be hikers, as it would have been getting dark. It is probably not wind as well. Therefore it is most likely animal activity or aircraft. Chances are, however, that it is an outlier rather than a significant finding, as no other day showed this spike. If it were aircraft, there would probably be a similar spike another day due to frequent aircraft flights.

Maintenance: This period should be ignored, and is not taken into consideration for the average calculations. This was the time when the team picked up and moved the equipment to the next site. It looks the way it does because of how the custom data processing software works.

General Ambient: Throughout most of the day, sound was fairly consistent. The rolling averages were for the most part flat and did not have high decibel spikes scattered throughout the hours. Days 1, 3, and 7 deviate away from this trend slightly however. It would make sense that Bernard Mountain, like Pine Hill, is fairly consistent as human traffic in the area is *very* low. Cadillac, on the other hand, tended to be slightly more sporadic with increasing sound levels throughout the day due to vehicles, wind and people. As stated earlier, the Tascam was unable to be set up. However, daily maintenance visits made it clear that most of the decibel readings can be attributed to birds, insects, distant aircraft, and occasional wind.

Due to the inability to listen to recordings from the site, no cross-referencing could be carried out for this site.

5.2.4 Gilmore Meadow

Site ID	4
Site Name	Gilmore Meadow
Measurement Dates	7/12/2013 – 7/19/2013
Latitude / Longitude (decimal degrees)	44.36273, -68.27729
Elevation (ft)	344
Land Class	Forested Upland
Site Description	Forest with soft ground covered with rocks, moss, branches, etc. Heavy insect level.
Access Notes	½ hike from marker 11 on Carriage Roads. Enter from eagle lake, head towards Aunt Betty Pond.
Possible Sound Sources	Wind, hikers, bikers, distant aircraft, birds, insects

Table 17: Gilmore Meadow ID Table

Table 18: Gilmore Meadow Setup

Due to a battery malfunction on site, too much data was lost for analysis. Therefore, there is neither an overall decibel graph to analyze nor are there intrusive sound graphs. *Refer to the next chapter (chapter 6: Future Work and Recommendations) for a more in depth explanation of what happened, and how this can be avoided in the future.* However, the team tried to make up for this loss of data by making extra audio recordings to scan through. The findings on general soundscape observations through these recordings will be made in this section.

Bird Activity: As with Cadillac, Pine Hill, and Bernard Mountain, all audio recordings revealed the same activity of birds waking up in the morning. The exact wakeup time is a little difficult to determine without decibel graphs, although it appears to be around the same time. This continues to suggest that bird activity is very consistent throughout the park, regardless of the surrounding environment of each location.

Airplanes: From the audio, the team determined a fairly high use of airplanes in the area of Gilmore Meadow. Although it cannot be determined how these airplanes intrude upon the natural soundscape of the area, it does continue to confirm the use of illegal flights over the park.

Unlike Pine Hill however, these planes tended to be lower to the ground (as the sound they produced was significantly louder). This might help explain why the overall average found for Gilmore Meadow in the 2005 study was higher than normal at 44.8 dBA. This could mean that other areas close to Gilmore Meadow are also being heavily affected. This is speculation however and needs to be looked into further.

General Ambient: It is interesting to note that the Gilmore Meadow recordings revealed high levels in birdcalls. Although every soundscape analyzed so far has contained birdcalls, this site's birdcalls were particularly loud. This could be due to a number of reasons:

1. Specific location of equipment was closer to bird habitats
2. General area has a higher numbers of birds
3. Breed of birds in area are different and produce louder calls

This is significant because it is another good proof of concept to show how sound can be used to explore nature. This is something the team did not expect to find going into the project. Not only can the recorder pick up birds, but also is sensitive enough to give a good idea as to how loud the calls are. As an example, this could be used to monitor the specific number of wildlife in an area. This could also be another reason why the average found in the 2005 study was so high.

Rain: One of the recordings was done during a brief rainstorm. This was interesting to pick up mainly because it revealed a possible source of data bias. Despite having a windscreen on the Tascam audio recorder, there were still quick, yet substantially loud spikes in sound levels due to water drops hitting sensitive parts of the recorder, specifically the microphone. It would not be a good idea to scratch all data collected during rainstorms because weather is an important aspect of a soundscape. A better idea would be to look into better windscreens that could dampen these impulse sounds more effectively. Granted, this was the Tascam recorder and not the XL2. However, chances are that the XL2's windscreen is about as effective in dampening this kind of sound. *Refer to the next chapter (chapter 6: Future Work and Recommendations) for a more in depth explanation of how this can be avoided in the future.*

5.2.5 Northeast Creek

Site ID	5
Site Name	Northeast Creek
Measurement Dates	7/19/2013 – 7/26/2013
Latitude / Longitude (decimal degrees)	44.41876, -68.31795
Elevation (ft)	69
Land Class	Wetlands
Site Description	Marshy area with heavy bushes and other vegetation. Heavy insect level.
Access Notes	1 mile hike from route 3, across the farm field. Used yellow Jeep Wrangler to drive across field after getting permission from owners.
Possible Sound Sources	Light wind, aircraft, birds, insects, motor vehicles

Figure 20: Northeast Creek ID Chart

Figure 21: Northeast Creek Setup

The following graph (*Figure 22*) shows the rolling average of the decibel readings for all seven days at Northeast Creek. Each day is represented in a different color, and each color is explained in the legend to the right. Important trends are expressed with colored dashed lines and explained after the graph.

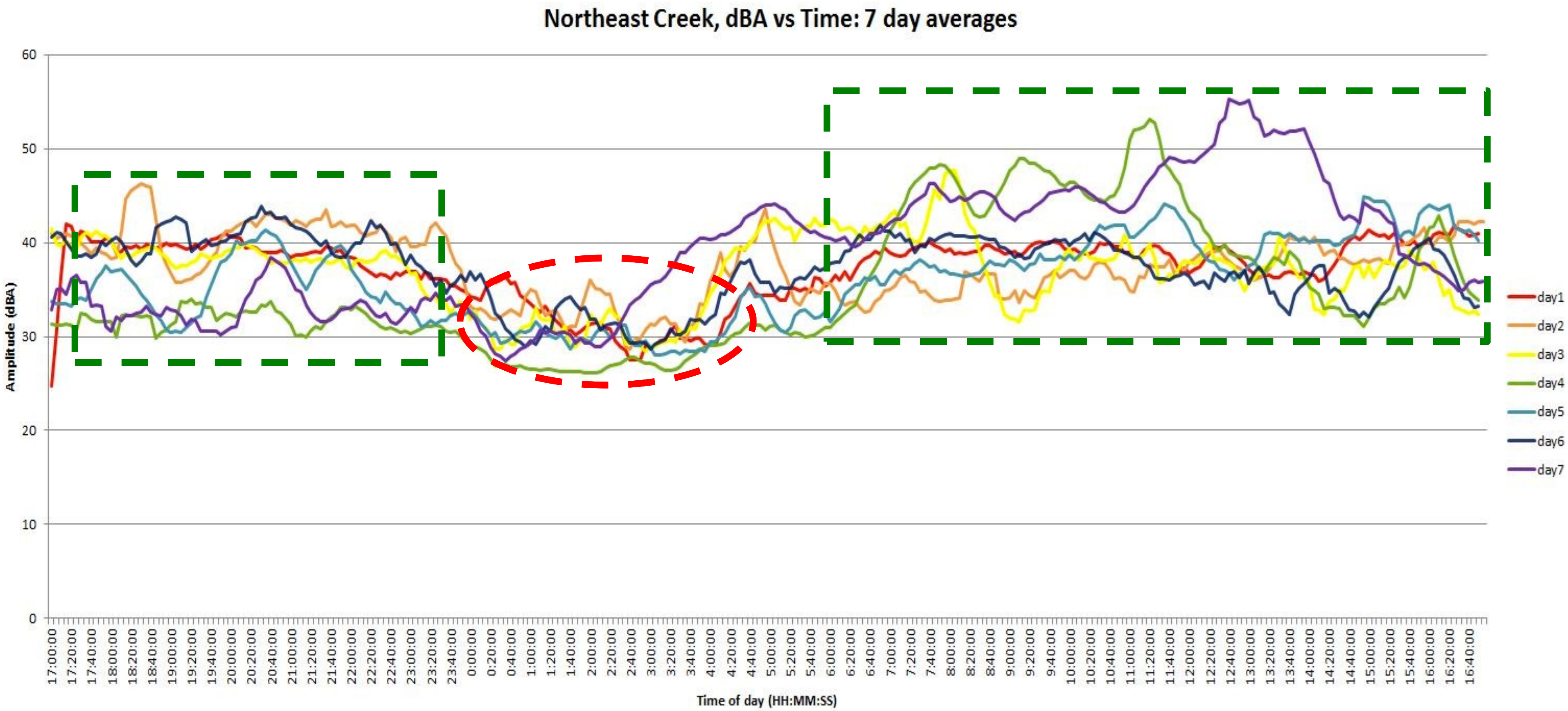


Figure 22: 7 Day Overlay of Decibel Readings at Northeast Creek

Bird Activity: As with all the other sites, audio recordings revealed the same activity of birds waking up in the morning. The exact wakeup time appears to be around the same time at 3:40 in the morning. This continues to suggest that bird activity is very consistent throughout the park, regardless of the surrounding environment of each location.

Motor Vehicles, Heavy Aircraft Use, and General Ambient: Although there were not very distinct trends throughout most of the data, audio recordings from the Tascam recorder and daily maintenance visits revealed a general ambient background with fairly consistent motor vehicle and aircraft noise. The team would observe jet airliners flying overhead at almost every visit and was able to pick out many individual plane flights using the Tascam. Furthermore, the audio recordings revealed a substantial number of planes in a very short period of recording. *Refer to Appendix F for intrusive sound graphs to see some of the decibel readings for plane flights overhead.* This is a significant result for 2 reasons:

1. It continues to confirm the use of illegal flights over the park
2. The overall sound quality in the area was affected by motor noise as it had the second largest decibel average

Point two is important to emphasize because unlike Pine Hill where aircraft and other motor noise did not significantly affect the overall sound quality of the area, Northeast Creek appeared to be more affected. This was apparent if you look at Table 8 that compares daytime and nighttime decibel readings. When compared to the deltas of the other sites, Northeast Creek's delta is substantially and consistently larger. This means that sound levels during the daytime, when airplanes are traveling more frequently, are significantly louder than during the nighttime. Another observation made by the team was during the daily visits. The team was far more distracted in comparison to other sites due to the noise levels from the planes and motor vehicles. Furthermore, the decibel readings shown in Figure 22 show very sporadic, or spikey readings. This is most likely due to irregular motor noise as there was very little wind present on site. There was also a constant drowning of vehicles because route 3 was about a mile away. The team thinks this is fairly consistent with the graphed readings. Although the lines are erratic, they tend to be bunched together. This would mean that the individual spikes in lines are due to the irregular car and aircraft noises, while the consistency of the lines being close together is due to the fact that traffic flow was fairly regular throughout the week.

What is also interesting to look at is the fact that the 2005 study also found Northeast Creek to be very aircraft heavy. This would mean that noise pollution levels from aircraft have been going on since the 2005 study, and are probably worse now because of increases in population. It is highly recommended that Northeast Creek continues to be heavily monitored in order to determine how damaging all the motor noise is to the area. Furthermore, future teams can look into ways to filter these vehicle noises at this specific location.

Refer to Appendix F for annotated graphs showing intrusive sounds upon Northeast Creek.

Chapter 6: Future Work and Recommendations

This study was created with the idea that it would be longitudinal. Essentially, this means that it will be continued for years to come. Future groups will build upon it every time further refining the process and design. Therefore, this chapter identifies and outlines possible directions that the study can evolve into. Furthermore, it highlights issues that arose over the course of the study that will be relevant for future work. Some possible solutions and suggestions are included.

6.1 New Direction

This project's methodology originated from the previous soundscape study done in 2005. It attempted to replicate the study and compare results. However, several alterations were made over the course of the study. Eventually, this methodology evolved and identified several new directions for future groups or studies to take.

For example, the 2005 study recorded sound levels at their specified locations for an average of twenty-five days. This is the amount of time the NPS recommends for sound level recording in order to eliminate bias and error in the data. However, this new study only recorded for seven days at each site. Due to this reduced recording time, the data from this study could not be guaranteed to the same standard that twenty-five days of data would be. However, the data gathered was close to the 2005 study's data when compared.

Thus, a new question has been posed. Is twenty-five days of data necessary or can smaller sampling times (like seven days) be used? Future studies could find an answer. A site would be selected to record for both seven and twenty five days. After the twenty-five day recording is completed, both sets of data would be compared. This would show that the data is completely different and seven days is not enough, or the two sets of data are extremely similar making seven days a justified recording time.

In addition to posing the question of recording time, new emphasis has been placed on observation and identifying sound sources. The previous study from 2005 was only concerned with aircraft noise. This new study was far broader in the search for sounds. Aside from aircraft, this study was interested in all sounds from human traffic, to motor vehicles, to birds and other wildlife. Observations indicated that a significant amount of noise came from sources other than aircraft, like motorcycles, wind, and birds. Future work might consider building profiles of these sources and expanding on identification using sound level data.

6.2 Equipment Considerations

The equipment used in this study varied greatly from what was used in the 2005 study. Great advancements were made between the two studies. The NTI XL2 sound level meter was an excellent choice due to its recording, analyzing and data logging capabilities. Furthermore, the NTI XL2 is capable of a whole host of other features than ones that were used in this study. It is highly recommended that future studies use this system or one similar to it and explore its capabilities in greater depth to suit their needs.

While the XL2 meter was perfectly suited for this project's needs, the power system was not optimal. The power system consisted of a single marine battery wired to be compatible with the meter's power inlet. With the meter's low power consumption the battery could last at least seven days. Much longer life is assumed (possibly over one month), however it was only allowed to run for one week before being swapped for the second battery and recharged. The problem was this method was susceptible to failure. While the system was deployed to Gilmore Meadow, power to the meter was interrupted. Since this site was only accessible from the carriage roads, it proved difficult to make daily trips to check on the equipment. Thus, the power failure was not noticed until a significant time later. Most of the data from the site was unable to be recorded. Future groups that wish to use a setup similar to this should consider improving upon the power system. Reliability and transportation were the main issues. For sites like Gilmore Meadow that are difficult to access, power reliability is key. Since the batteries are fairly heavy, it was difficult to transport a replacement to the site. Groups should consider a system that is capable of generating power on site and has several redundancies to account for the threat of failure.

In addition to modifications to the power system, future studies should consider the weather protection equipment. The waterproof case and windscreen did provide adequate protection against weather and prevented the equipment from malfunctioning due to moisture and rain.

However, it was unable to completely eliminate the bias from rain hitting the box and microphone. It was difficult to remove the bias due to the nature of the equipment. The microphone had to be somewhat exposed to be able to record, however exposing too much would risk damage and unwanted noise. Attempts were made using cloth to dampen the impact sounds from rain, however in the data from Gilmore Meadow the rain hitting the equipment elevated decibel levels significantly at times. Unfortunately, simply eliminating the data would have been impossible because rain is an important element of soundscapes. Thus, future groups will need to redesign weather protection to account for this bias.

As previously mentioned, this project evolved to include a lot of observation to identify sound sources. The main tool was the Tascam digital audio recorder. While this helped tremendously in making several positive identifications, many man hours were spent manually sorting through the recordings. Future groups should try to discover a more efficient way of recording and matching the audio to sound level data. The XL2 is capable of audio recording and this project never explored that option. If future groups do use the XL2, it might be possible to simultaneously record audio and sound level data. Hopefully this would have corresponding timestamps allowing for easy cross-referencing.

6.3 Observation

A key aspect that evolved from this study was the ability to identify sound sources and link them to the sound level data. This was achieved through deployment of the digital audio recorder. It allowed for the matching of simple decibel data to actual sound sources. Earlier it was mentioned that at Cadillac Mountain, the spike just before four in the morning was identified as birds beginning to sing. Although there was tremendous success in identifying sources, the system proved to be extremely inefficient. Several hours of the digital sound files had to be analyzed manually. In the previous study, researchers sat outside at the sites with notepads and recorded observations of traffic and sound sources. While this new study made advancements by using audio recording, both studies proved to have incredibly inefficient observation methods. Since this study has evolved to include identifying where sound comes from and what impact it has, future studies should devise a more efficient and effective way of observing sound sources and linking them to the sound level data.

6.4 Accessibility

This study used sites directly from the list of those used in the 2005 study. Below is a map of the sites used in the 2005 study.

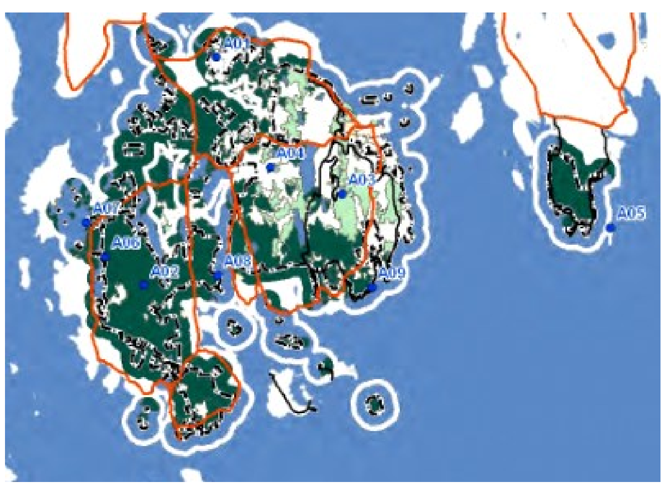


Figure 23: 2005 Sites

The blue dots represent all of the sites used by the 2005 study. Due to accessibility and time limitations, however, only five of them were used in this study. Site A05 (on Schoodic Peninsula) was not used due to the amount of time it would take to drive there and back. Also, sits A07, A08 and A09 were not used due to time constraints. This project was only scheduled for seven weeks, so some sites had to be eliminated. However, future groups should consider gathering data at these locations as they are very important to the study as well.

Site A04 is Gilmore Meadow. This site proved the most difficult out of the five done by this study. It was determined that access is only available through the carriage roads. Thus it was difficult to visit daily. As mentioned earlier, this was an obstacle when one of the batteries failed because bringing the heavy battery out there was difficult, and the failure was noticed too late. Additionally, site A01 is Northeast Creek. The actual coordinates from the 2005 study could not be reached due to the creek's seasonal flooding of the access point. Thus, the equipment was placed on the near side of the creek. However, the site was still somewhat difficult to access without an off-road capable vehicle because of its location across a field of tall grass. Luckily the team had access to a yellow Jeep Wrangler making accessibility to the site easier. In the future, teams should reevaluate the locations of the sites and possibly find easier alternatives to these two. Otherwise, they will have to tailor equipment and visitation strategies.

Chapter 7: Conclusion

This project was completed and over the course of its seven-week period a lot of valuable data was gathered. After analyzing the averages and comparing them to those of the 2005 study, it was noted that this study's data was very close to that of the 2005 study. The lowest percent difference was 0% at Cadillac Mountain. Bernard Mountain had the highest percent difference at 15.5%. While 15.5% difference is significant, it is still on the low end and the overall average values were all deemed significantly close to the original.

Unlike the overall sound level averages, the percentile (L_{50} and L_{90}) differences were quite significant. Many of them were in the 25% area, with some even being over 100%. Unfortunately, it was impossible to prove if this was due to seven days of recording versus the recommended twenty-five or due to an overall increase in sound levels since 2005. Future studies will be needed to determine the source of this significant difference.

In addition to comparing sound levels to those of the 2005 study, this project focused on improving and altering the methodology. The methodology evolved to have more focus on observation and correlation with data and sound sources. Instead of focusing on pure number averages and looking for a single source, it was improved to focus on identifying all different sound sources and their impact on the data. Included in these revisions was a redesign of the equipment setup. This study was able to take advantage of technological advances and gather data using a much more compact, user friendly set up. Hopefully future studies will be able to utilize and improve upon advances made here.

Overall, this project was incredibly successful. A new methodology was implemented and tested extensively with very satisfactory results. Work will not end with this study. There was a lot of room left for future groups to expand upon what was discovered and lead to further improvements in soundscape research. Acadia National Park staff were left with a multitude of valuable data they can use to help manage the Park's soundscape as well as breakthroughs in soundscape research techniques.

Appendix A: Equations

$$SPL = 20\log_{10}\left(\frac{p}{p_0}\right)$$

Equation 2: db Equation

Where p is the measured pressure level, and p_0 is the reference pressure level, defined to be 2 x 10^{-5} N/m^2 (the human threshold of hearing at a 4 KHz frequency). The unit associated with amplitude is the decibel, abbreviated as dB.

$$f_{n-1} = \frac{f_n}{\sqrt{2}^{\left(\frac{1}{3}\right)}}$$

Equation 3: Central Frequency Equation

Where f_n is the current central frequency and f_{n-1} is the next lowest central frequency *(Refer to Appendix A for standard 1/3 octave band frequencies table).* A standard ⅓ octave plot is illustrated in Graph 1 in Appendix A.

$$f_{low\ bound} = f_n * 2^{\left(\frac{1}{3}\right)}$$

$$f_{high\ bound} = \frac{f_n}{2^{\left(\frac{1}{3}\right)}}$$

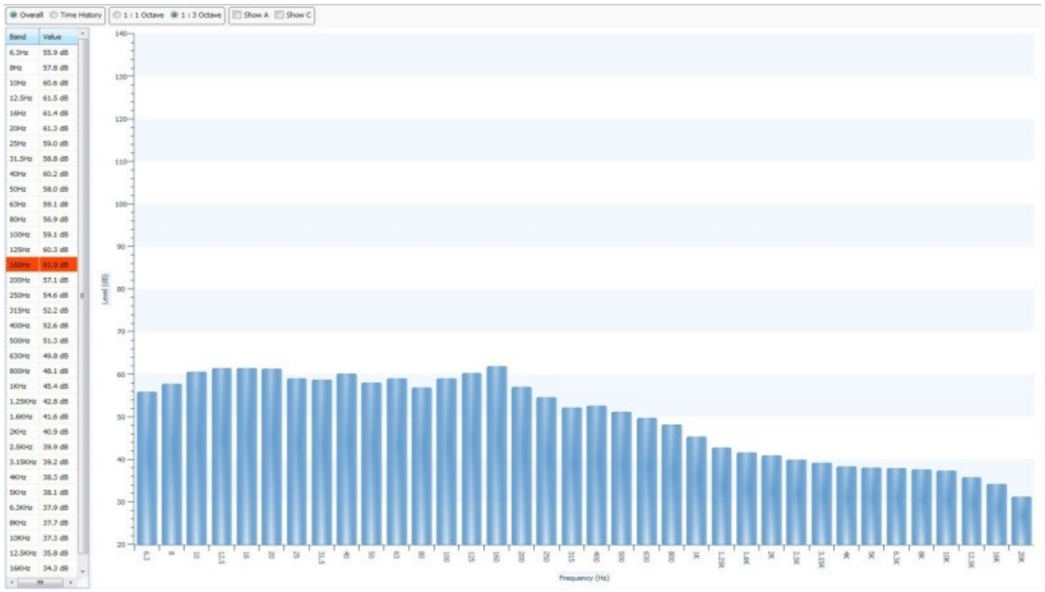
Equation 4: 1/3 Upper and Lower Octave Frequency Bands

Where f_n is the current central frequency and $f_{low\ bound}$ and $f_{high\ bound}$ are the lower and upper band frequencies for a given central frequency. This gives a 1/3 octave band range.

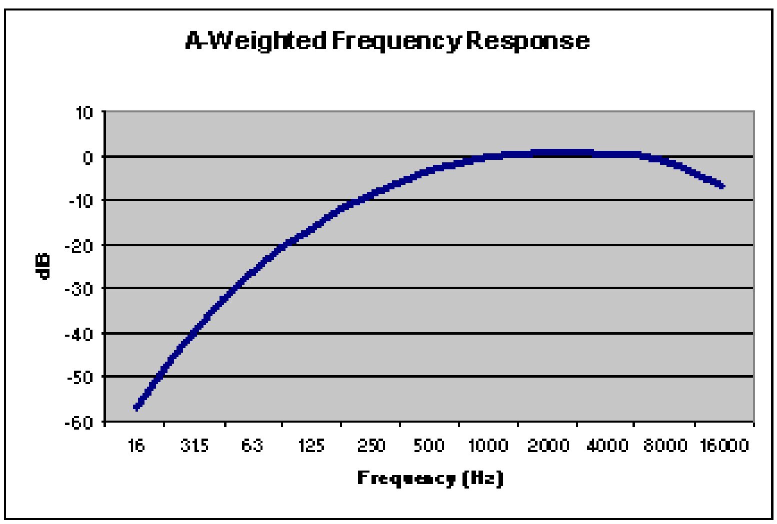
Appendix B: Tables and Graphs

	FREQUENCY					
	OCTAVE			ONE-THIRD OCTAVE		
BAND	LOWER BAND LIMIT	CENTER	UPPER BAND LIMIT	LOWER BAND LIMIT	CENTER	UPPER BAND LIMIT
12	11	16	22	14.1	16	17.8
13				17.8	20	22.4
14				22.4	25	28.2
15	22	31.5	44	28.2	31.5	35.5
16				35.5	40	44.7
17				44.7	50	56.2
18	44	63	88	56.2	63	70.8
19				70.8	80	89.1
20				89.1	100	112
21	88	125	177	112	125	141
22				141	160	178
23				178	200	224
24	177	250	355	224	250	282
25				282	315	355
26				355	400	447
27	355	500	710	447	500	562
28				562	630	708
29				708	800	891
30	710	1,000	1,420	891	1,000	1,122
31				1,122	1,250	1,413
32				1,413	1,600	1,778
33	1,420	2,000	2,840	1,778	2,000	2,239
34				2,239	2,500	2,818
35				2,818	3,150	3,548
36	2,840	4,000	5,680	3,548	4,000	4,467
37				4,467	5,000	5,623
38				5,623	6,300	7,079
39	5,680	8,000	11,360	7,079	8,000	8,913
40				8,913	10,000	11,220
41				11,220	12,500	14,130
42	11,360	16,000	22,720	14,130	16,000	17,780
43				17,780	20,000	22,390

Table 19: 1/3 Octave Band Frequencies (2010)



Graph 3: Standard 1/3 Octave Band Spectrum ("[One Third Octave Band Graph].")



Graph 4: A-Weighted Frequency Response Curve

Appendix C: Setup Procedure

This section shows the step-by-step procedure for how to set up the equipment used in this project. The following picture shows all the tools needed to properly setup the recording equipment and begin collecting data:

Figure 24: Entire Setup

1. Tripod (2) – to mount the XL2 and TASCAM
2. Bungee cords – to secure the waterproof case on the tripod
3. Waterproof case – to protect the XL2 from harsh weather
4. Rope – to provide extra support to the tripod
5. GPS – to locate the desired locations
6. XL2 – to measure and record the sound levels and frequencies
7. Waterproof windscreens – to protect the XL2 microphone from the rain
8. TASCAM – to record audio
9. Windscreen for TASCAM – to protect TASCAM microphones
10. Marine battery – to power the XL2

Before starting, a few adjustments had to be made to the waterproof box to fit the XL2. The adjustments are shown in the following figure:

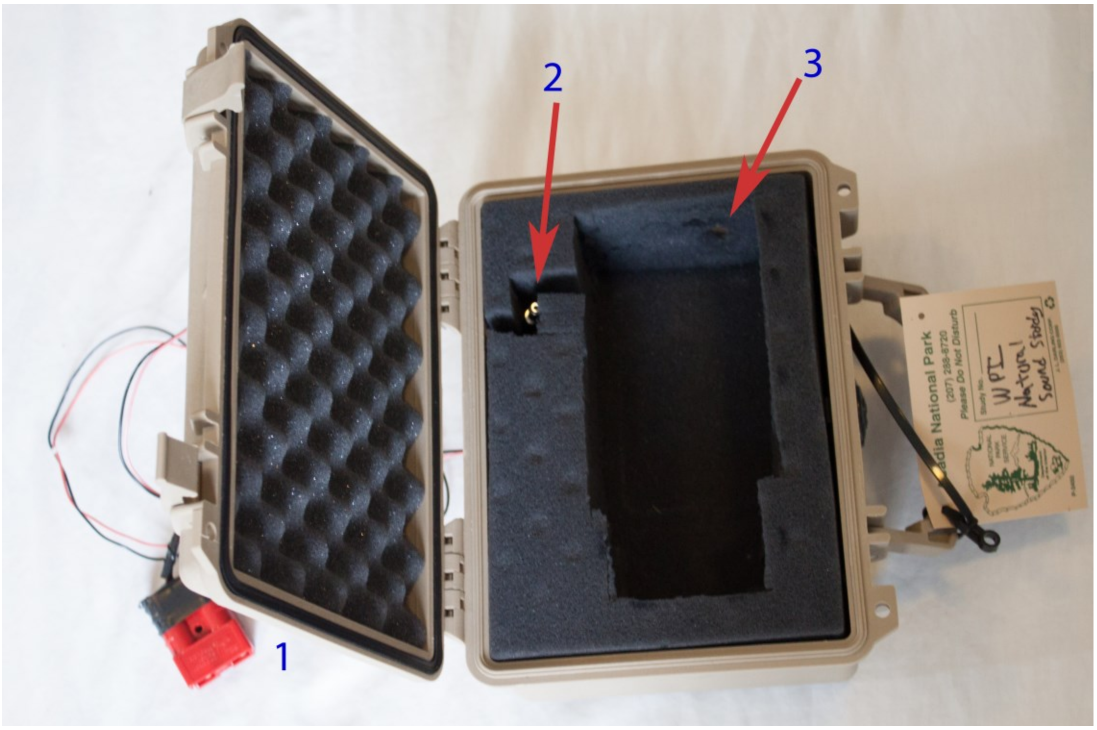


Figure 25: Modified Waterproof Case (1)

1. Use/rig power cords that connect the XL2 to the battery.
2. Create a hole in the box for the power cord and make sure it is well insulated.
3. Create another hole for the XL2 microphone.

Figure 26: Modified Waterproof Case (2)

Next, place the XL2 in the waterproof box with caution as not to damage the microphone. Connect the XL2 to the power source using the power cord. Then, turn on the XL2 and change the settings as desired. A user manual for the XL2 operating instructions and other information about the XL2 can be found in appendix C.

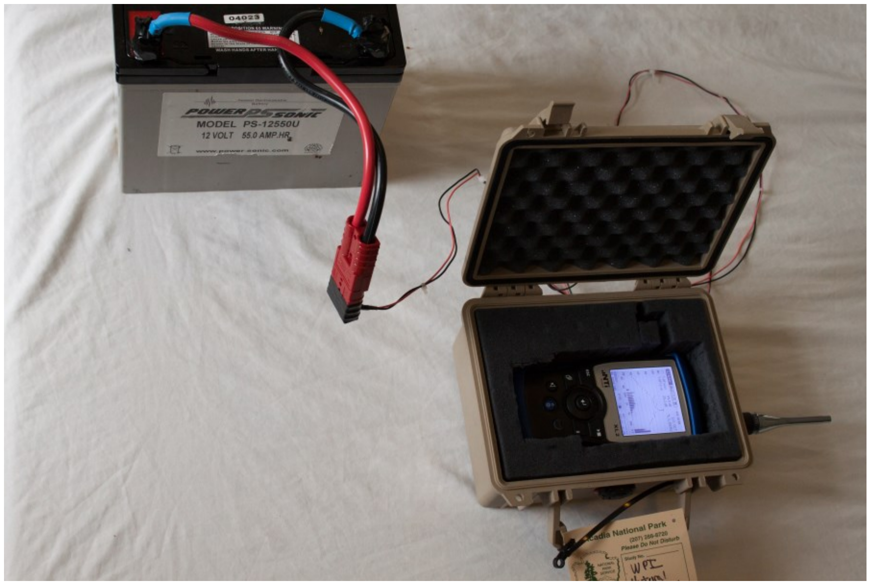


Figure 27: XL2 Inside Waterproof Case and Wired To Battery

Once the XL2 starts recording, secure the waterproof box by locking both secure latches

Figure 28: Waterproof Case Latched Closed

Next, use the bungee cords to attach the box to the tripod. Take special care to make sure that the bungee cords do not interfere with the power cords.

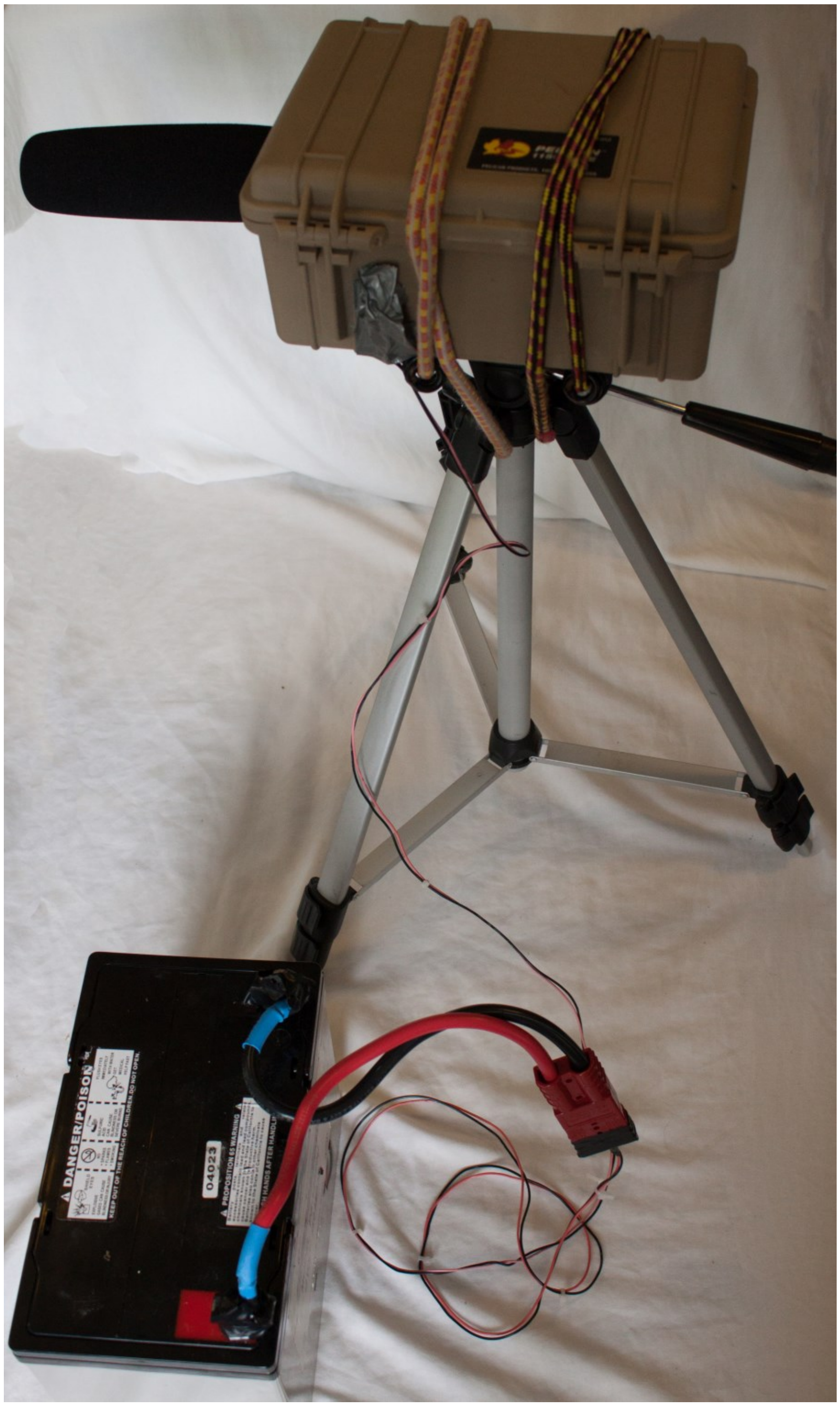


Figure 29: Case Attached To Tripod Using Bungee Cords

Figure 30: Close-up of Case Attached To Tripod

Once it is time to collect the data, carefully unhook the bungee cords and open the lid to the waterproof box. Stop the recording and save the data files. Optionally, record a voice note.

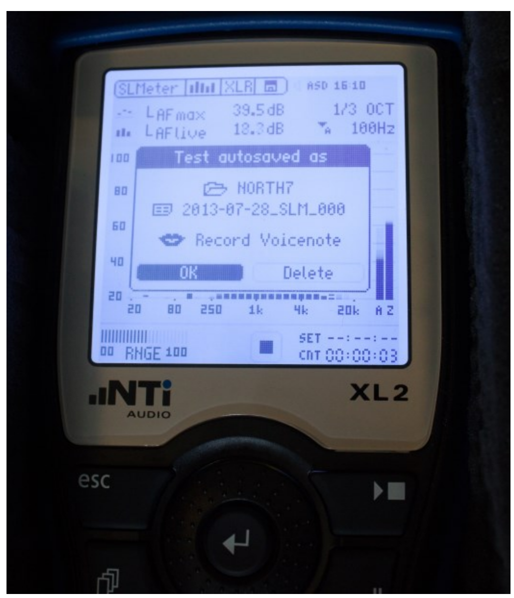


Figure 31: Screenshot of Saving Data on XL2

Next, turn off the XL2 to safely remove the micro SD card. Remove the micro SD card from the bottom side of the XL2. It is more convenient to do so while the XL2 is still in the box but it requires more caution, making sure to not harm the microphone which is still attached.

Figure 32: Micro SD Card Slot on Bottom of XL2

After the micro SD card has been removed, a micro SD card converter will probably have to be used depending on the computer. For this project, a micro SD to USB converter card reader was used to transfer the data files to a computer.

Figure 33: Micro SD to USB Converter

To record audio, the TASCAM audio recorder was used. To begin recording, attach the TASCAM audio recorder to the tripod. The TASCAM has a standard tripod screw mount. Then, use the appropriate windscreen to cover up the microphones.

Figure 34: Tascam Audio Recorder Without Windscreen

Figure 35: Tascam Audio Recorder With Windscreen

Finally, to retrieve the audio files from the TASCAM, follow the same procedure used for the XL2

Appendix D: Equipment

D.1 XL2 and M2230 References:

Website for XL2 sound analyzer: http://www.nti-audio.com/en/products/xl2-sound-level-meter.aspx

Website for M2230 microphone: http://www.nti-audio.com/en/products/measurement-microphones.aspx

XL2 User manual: http://www.nti-audio.com/Portals/0/data/en/XL2-Manual.pdf

M2230 microphone user manual: http://www.nti-audio.com/Portals/0/data/en/Measurement-Microphones-Manual.pdf

XL2 data sheet: http://www.nti-audio.com/Portals/0/data/en/XL2-Specifications.pdf

M2230 microphone data sheet: http://www.nti-audio.com/Portals/0/data/en/Measurement-Microphones-Specifications.pdf

D.2 Tascam DR – 40 Digital Audio Recorder References:

Website for DR – 40: http://tascam.com/product/dr-40/

DR – 40 specs: http://tascam.com/product/dr-40/specifications/

D.3 Weather Protection References:

Pelican Waterproof Box Website: http://www.pelican.com/

Auray WSF-2216-WP Windscreen Website: http://www.bhphotovideo.com/c/product/888908-REG/auray_wsf_2216_wp_waterproof_windscreen_for_ntg_2_others.html

D.4 Battery Specs:

Cost: Approx. $130 (Not including shipping)

Product Dimensions: 9.7 x 5.5 x 9.2 inches

Shipping Weight: 40 pounds

Item model number: 8A22NF

Voltage: 12

Amp Hours: 55

Type: Sealed lead acid AGM

Estimated battery life with XL2: 66 hours, or 2.75 days

Appendix E: Python Script Source Code

To use the software that was created for this project, the source code has been hosted and open sourced online at Github.com, and can be downloaded directly from:

https://github.com/mscosti/soundscape-analyzer

For accessibility, the source code has been printed below for each of the four Python files. The following files are completely functional but cannot be guaranteed to be the most up to date version. For the complete version please view the source code on Github.

AutomatedGenerateAll.py

```
'''
Created on Jul 1, 2013

This is a script to automate the entire data generating process involved with
parsing the raw data from the XL2 textfiles, and generates all the neccessary
excel readable CSV Files. These CSV files can be used for graphing and visualizing
the data quickly and easily. There are many types of files that are automatically
generated for the user, listed below

'All_site_3rd_day#' : All the data points from one day representing the 1/3 octave frequencies
'All_site_3rd_Stitch : one CSV file containing all the days of 1/3 octave frequency readings, stitched
together
'All_site_DB_day#' : All the decibel readings from one day of recording
'site_3rd_day#' : The averaged 1/3 octave frequency columns for one day of recording
'site_DB_day#' : 5 minute samples of the DB readings from one day, used for graphing purposes
'site_Stitch' : one CSV file that contains all the days of DB readings stitched together
'site_stitch_moving_avg' : the same as above, but with a 3rd column representing the moving average points

@author: Matt
'''
```

```python
import os
import csv
import CreateCSV as create
import stitching_data as stitch
import Calc_Statistics as calc


#Variables that the user must specify.
#raw:      The complete path where all of the raw db and raw 3rd data files from the XL2 are located.
#site:     The complete site name (safest without spaces) that all generated files will use in their
#          file names.
#update:   update should be marked as 'True' if the user wants to check to regenerate stitched files
#          with newer data files or days. The user should mark 'False' if they do not want to run the
#          stitching programs at this time
#cut:      cut should be true if the user wants to run the cutting program that cuts out the bad times
#          in their data

raw = "C:\Users\Matt\Documents\IQP\PINEHILLTEST\RawData"
site = "PineHill"
update = True
cut = False

#Interference and maintentance times specified in this cutTimes list in the format
# [[[date],[startTimeCut],[endTimeCut]],[...],[...]]
# [[YYYY,DD,MM],[hh,mm,ss],[hh,mm,ss]]
#
# List all times to be cut
#
# NOTE: Cut times are only applied to 'All' files that would be used for computing
# averages on the basis that maintenence interference would not greatly impact
# the sampled graphs for viewing purposes.
cutTimes = [[[2013,6,28],[10,00,00],[17,05,00]],
            [[2013,6,29],[17,00,00],[17,20,00]],
            [[2013,6,30],[16,51,00],[17,8,00]],
            [[2013,7,1],[16,52,00],[17,9,00]],
            [[2013,7,2],[16,17,00],[16,30,00]],
            [[2013,7,3],[17,01,00],[17,22,00]],
            [[2013,7,4],[17,50,00],[18,06,00]],
            [[2013,7,5],[15,40,00],[17,20,00]]]

#create the raw dir if the one given doesn't exist
```

```python
if not os.path.exists(raw):
    os.makedirs(raw)

#change directories to given path with raw data and get parent
os.chdir(raw)
parent = os.path.split(raw)[0]
dbDay = os.path.join(parent,'dbDaily')
freqDay = os.path.join(parent,'3rdDaily')
dbAll = os.path.join(parent,'AllDB')
freqAll = os.path.join(parent,'All3rd')

#A list of all the raw data files
list = os.listdir(raw)

#A list of all the generated files inside of the main site location folder
parentList = [x.split('.')[0] for x in os.listdir(parent)]

#Loops through the raw data files in the directory given,
#creating the daily decibel csv files for graphing (5 minute sample)
#along with the spectrogram data. Both types of files are created
#in the parent directory of the raw files folder
dayCnt = 0
print 'begin'
for count,file in enumerate(sorted(list)):
    if count %2 == 0: #increments the day counter every other file
        dayCnt += 1
    dbFileName = site+'_DB_day'+str(dayCnt)#Create the new decibel file name
    specFileName = site+'_3rd_day'+str(dayCnt)#Create the new spec file name

    print file
    #If the current file is a DB file
    if file.split('_')[3] == '123':

        if dbFileName not in parentList: #If the dbFile is not already generated
            dbData = create.CSVcreate(db_file=file)
            dbData.db_CSV(os.path.join(parent,dbFileName+'.csv'), True)#Create the sampled dB CSV file

        if 'All_'+dbFileName not in parentList: #if the All_dbFile is not already generated
            dbData = create.CSVcreate(db_file=file)
            unsampledFileName = 'All_' + dbFileName
```

```
            dbData.db_CSV(os.path.join(parent,unsampledFileName+'.csv'),False)#Create the All_dB unsampled 
CSV file

    #If the current file is a Frequency file
    elif file.split('_')[3] == 'RTA':

        if specFileName not in parentList: #If the specFile is not already generated
            specData = create.CSVcreate(spec_file=file)
            specData.spec_CSV(os.path.join(parent,specFileName+'.csv')) #Create the freq CSV file

        if  'All_'+specFileName not in parentList: #If the All_specFile is not already generated
            specData = create.CSVcreate(spec_file=file)
            specData.write_All_Spec(os.path.join(parent,'All_'+specFileName+'.csv')) #Create the 
All_specFile CSV file

#make to change directory to the parent, main site folder
os.chdir(parent)

#if the db Stitch file is not already generated, or it is desired to update the file,
#then create or update the stitch file with all available day files
if site+'_Stitch' not in parentList or update:
    stitch.stitch(site+'_Stitch.csv', True,
                  site+'_DB_day1.csv',
                  site+'_DB_day2.csv',
                  site+'_DB_day3.csv',
                  site+'_DB_day4.csv',
                  site+'_DB_day5.csv',
                  site+'_DB_day6.csv',
                  site+'_DB_day7.csv')

    #calculate the rolling average for the stitched dB file for graphing purposes and put
    #it in a seperate file
    stitch.appendAverages(site+'_Stitch.csv', 7)

#if the All_db Stitch file is not already generated, or it is desired to update the file,
#then create or update the stitch file with all available day files
if 'All_'+site+'_Stitch' not in parentList or update:
    stitch.stitch('All_'+site+'_Stitch.csv', False,
                  'All_'+site+'_DB_day1.csv',
                  'All_'+site+'_DB_day2.csv',
                  'All_'+site+'_DB_day3.csv',
```

```
                  'All_'+site+'_DB_day4.csv',
                  'All_'+site+'_DB_day5.csv',
                  'All_'+site+'_DB_day6.csv',
                  'All_'+site+'_DB_day7.csv')

#if the All_3rd freq Stitch file is not already generated, or it is desired to update the file,
#then create or update the stitch file with all available day files
if 'All_'+site+'_3rd_Stitch' not in parentList or update:
    stitch.stitch('All_'+site+'_3rd_Stitch.csv', False,
                  'All_'+site+'_3rd_day1.csv',
                  'All_'+site+'_3rd_day2.csv',
                  'All_'+site+'_3rd_day3.csv',
                  'All_'+site+'_3rd_day4.csv',
                  'All_'+site+'_3rd_day5.csv',
                  'All_'+site+'_3rd_day6.csv',
                  'All_'+site+'_3rd_day7.csv')

if cut:
    for timeStamp in cutTimes:
        calc.cutTime('All_'+site+'_Stitch.csv',timeStamp[0],timeStamp[1],timeStamp[2])
        calc.cutTime('All_'+site+'_3rd_Stitch.csv',timeStamp[0],timeStamp[1],timeStamp[2])

#For right now, you can only run one statistics function at a time. Uncomment the one you need, and run

#hourlyLeq,hourlyL50,hourlyL90 = calc.averageHourly('All_'+site+'_Stitch.csv')
#ovrLeq,overL50,overL90 = calc.overallAverages('All_'+site+'_Stitch.csv')
#dayAvg,nightAvg = calc.dayNightAverages('All_'+site+'_Stitch.csv')
```

CreateCSV.py

```
'''
Created on Jun 24, 2013

CreateCSV.py contains a class named CSVcreate, which contains methods
for creating various csv files from scratch in the current directory.

When making a CSVcreate object, you have to specify the 'db_file' and
the 'spec_file', so that it knows what raw data it has to look at.

Depending on the CSV method you choose, different types of decibel and
frequency files will be generated.

@author: Matt
'''

import csv
import datetime

class CSVcreate:
    #the constructor takes optional parameters for db and spec file locations
    def __init__(self,*args,**kwargs):
        self.dbFile = kwargs.get('db_file')
        self.specFile = kwargs.get('spec_file')

    #method for parsing the raw db File that grabs all of the timestamps and corresponding
    #dB level. If sample is set to true, it grabs a reading only every 5 minutes
    def db_CSV(self,dest_name,sample):

        #get the lines to be read, and the staring line
        raw_lines, line_cnt = self.get_starting_line(self.dbFile,"# Broadband LOG Results",3)

        #set up the CSV writer
        db_csv = open(dest_name,'wb')
        db_writer = csv.writer(db_csv,dialect='excel')

        count = 0
        first = True
        beginCount = False
```

```
    timeStart = datetime.time(16,55,0)
    startDay = None

    #begin looping through ever line starting at line_cnt
    for line in raw_lines[line_cnt:]:
        data_point = line.split()
        if len(data_point) > 1:

            dayDate = data_point[0]+ ' '+ data_point[1]
            year,month,day = dayDate.split(' ')[0].split('-')
            hours,mins,secs = dayDate.split(' ')[1].split(':')

            year = int(year)
            month = int(month)
            day = int(day)
            hours = int(hours)
            mins = int(mins)
            secs = int(secs)

            date = datetime.date(year,month,day)
            time = datetime.time(hours,mins,secs)
            current = datetime.datetime.combine(date,time)

            #if has been 5 minutes and the user wants to sample
            if mins%5 == 0 and secs == 0 and sample:
                #write the merged timestamp and decibel reading
                db_writer.writerow([data_point[0]+ ' '+ data_point[1],data_point[3]])
                count = 0
            elif not sample:
                db_writer.writerow([data_point[0]+ ' '+ data_point[1],data_point[3]])
        else:
            print count
            break


    print "Decibel readings CSV File created with filename '%s'"%dest_name

#grabs the already computed averages and the proper frequency labels from the raw frequency file,
#and writes them to a excel file for graphing.
def spec_CSV(self,dest_name):
```

```
        #get the lines to be read and the staring line of the Hz Labels
        raw_lines,line_cnt = self.get_starting_line(self.specFile,"# RTA LOG Results LAeq_dt",1)

        all_vals=raw_lines[line_cnt].split()
        print all_vals

        #get the Hz Labels and convert them to floats
        HZ_vals = all_vals[8:]
        for item in range(len(HZ_vals)):
            HZ_vals[item] = float(HZ_vals[item])

        #get the next starting line where the frequency values begin
        raw_lines,line_cnt = self.get_starting_line(self.specFile,"# RTA LOG Results LAeq over the whole
log period",1)
        all_db_vals = raw_lines[line_cnt].split()
        db_vals = all_db_vals[6:]

        #loop through converting each value to a float
        for item in range(len(db_vals)):
            if db_vals < 50:
                db_vals[item] = float(db_vals[item])

        #prepare the CSV writer
        spec_csv = open(dest_name,'wb')
        spec_writer = csv.writer(spec_csv,dialect='excel')

        #write the HZ values and then write the corresponding decibel readings
        spec_writer.writerow(HZ_vals)
        spec_writer.writerow(db_vals)


    #Grabs and writes all of the readings from the entire file, not just the averages
    def write_All_Spec(self,dest_name):
        raw_lines,line_cnt = self.get_starting_line(self.specFile,"# RTA LOG Results LAeq_dt",3)

        reader = open(self.specFile).read().strip().split('\n')
        writer = csv.writer(open(dest_name,'wb'))
        counter = 0
        for row in reader:
            row = row.split()
            if counter >=line_cnt:
```

```
            if not row or len(row) < 35:
                break
            dateStamp = row[0]+ ' '+ row[1]
            writer.writerow([dateStamp]+map(float,row[6:]))
            counter +=1
        counter +=1

    #searches for a specific string (delimeter) in the input file, and returns
    #that line number, plus the amount of lines input for skipln
    def get_starting_line(self,file,delimeter,skipln):
        raw_db = open(file)
        raw_lines = raw_db.read().split('\n')
        line_cnt = 0
        for line in raw_lines:
            if str(line) == delimeter:
                print "done!"
                line_cnt += skipln
                break;
            line_cnt += 1
        return raw_lines,line_cnt
```

StitchingData.py

```
'''
Created on Jun 24, 2013

stitching_data stitches already created CSV files for seperate days into
one large seemless CSV file, with different options and methods useful for
graphing or calculating statistics on

@author: Matt
'''
import csv
import numpy
import os
import datetime
```

```
#Takes a new destination file name, a lineGap boolean, and a list
#of all the filenames to stitch togeteher.
#
#The boolean Linegap should be set as true if there is to be a linegap
#after each days worth of data, which makes graphing the overlay graphs
#much easier
def stitch(dest,lineGap,*filenames):
    first = True

    timeStart = datetime.time(17,0,0)
    timeEnd = datetime.time(16,59,59)

    stitch_csv = open(dest,'wb')
    writer = csv.writer(stitch_csv,dialect='excel')

    for count, file in enumerate(filenames):
        if os.path.exists(file):
            csv_reader = csv.reader(open(file,'r'))
            next_day = None
            for row in csv_reader:
                year,month,day = row[0].split(' ')[0].split('-')
                hours,mins,secs = row[0].split(' ')[1].split(':')

                #Convert all date data into ints
                year = int(year)
                month = int(month)
                day = int(day)
                hours = int(hours)
                mins = int(mins)
                secs = int(secs)
                d = datetime.date(year,month,day)
                t = datetime.time(hours,mins,secs)

                dayDate = datetime.datetime.combine(d,t)

                #get to first day of data starting at 1700
                if lineGap:
                    stamp = row[0].split(' ')[1]

                if first == True:
                    startDay = datetime.datetime.combine(d,timeStart)
```

```
                endDate = startDay + datetime.timedelta(days=1)
                nextDay = datetime.datetime.combine(endDate,timeEnd)

                first = False

            if dayDate >= startDay and dayDate < nextDay:
                if lineGap:
                    writer.writerow([stamp,row[1]])
                else:
                    writer.writerow(row)

            if dayDate >= nextDay:

                if lineGap:
                    writer.writerow('')

                startDay = datetime.datetime.combine(d,timeStart)

                endDate = startDay + datetime.timedelta(days=1)#datetime.date(year,month,day+1)
                nextDay = datetime.datetime.combine(endDate,timeEnd)

                if lineGap:
                    writer.writerow([stamp,row[1]])
                else:
                    writer.writerow(row)
    print 'done appending averages'

#takes an existing destination CSV file and a window size, and
#calculates a moving average on the data
#
#window_size specifies how far ahead to look when calculating the moving
#average, and therefore how smooth the generated curve would be
def movingaverage(dest, window_size):
    data = csv.reader(open(dest,'r'))
    window= numpy.ones(int(window_size))/float(window_size)
    decibels = []
    for row in data:
        if row:
            if len(row) == 2:
                date = row[0]
```

```
                db = row[1]
                decibels.append(float(db))
    return numpy.convolve(decibels, window, 'same')

#Takes an existing destination that is already fully stitched
#and appends the moving average into a new column of the CSV File
def appendAverages(dest,window_size):

    #gets the list of averages to be appended
    averages = movingaverage(dest,window_size)
    counter = 0

    #prepare the CSV Writer
    avg_file = dest[0:-4] + '_moving_avg.csv'
    avg_writer = csv.writer(open(avg_file,'wb'))
    avg_reader = csv.reader(open(dest,'r'))

    for row in avg_reader:
        if row:
            row.append(averages[counter]) #appends the average to this row
            avg_writer.writerow(row)
            counter += 1
        else:
            avg_writer.writerow('')
```

Calc_Statistics.py

```
'''
Created on May 18, 2013

Calc_Statistics is used for all the different type of calculations that can be done
on the data already contained in CSV files


@author: Matt Costi

'''
import csv
import operator
import datetime
```

```
#Calculates both the L50 and L90 percents for a given file
def nthPercent(dbFile):
    csv_reader = csv.reader(open(dbFile,'r'))
    sortedList = sorted(csv_reader, key=operator.itemgetter(1), reverse=False)
    l = len(sortedList)
    print sortedList[:20]
    l50 = sortedList[l/2]
    l90 = sortedList[l-int(l * .9)]
    return l50[1],l90[1]

#Cuts data at specific timestamps from the given file, usually because of
#maintenance and interference
#
#input date format: [year,month,day]
#input time format: [hour,mins,sec]
def cutTime(dbFile,date,sTime,eTime):
    #prepare the CSV Reader, opening the specified file
    reader = csv.reader(open(dbFile, 'r'))

    #convert the entered timestamps into start and end datetime objects
    start = datetime.datetime(date[0],date[1],date[2],sTime[0],sTime[1],sTime[2])
    end = datetime.datetime(date[0],date[1],date[2],eTime[0],eTime[1],eTime[2])

    #list that contains all of the data that is not cut
    correctedData = []
    for row in reader:
        if row:
            #parses the neccessary time info from the row
            year,month,day = row[0].split(' ')[0].split('-')
            hours,mins,secs = row[0].split(' ')[1].split(':')

            #Convert all date data into ints
            year = int(year)
            month = int(month)
            day = int(day)
            hours = int(hours)
            mins = int(mins)
            secs = int(secs)

            #the current timestamp object in the row
```

```
            timeStamp = datetime.datetime(year,month,day,hours,mins,secs)

            #if the timestamp lies between the start and end times, do nothing
            if start <= timeStamp and timeStamp <= end:
                None
            elif row:
                correctedData.append(row)

    #prepare the CSV Writer and overwrite everything in the given file with
    #the corrected data points
    writer = csv.writer(open(dbFile,'wb'),dialect='excel')
    for row in correctedData:
        writer.writerow(row)

#takes a stitch of site's complete,un-sampled,
#week of data and averages each hour
def averageHourly(siteFile):
    hours = {}
    averages = {}
    l50 = {}
    l90 = {}

    #prepare the CSV Reader
    reader = csv.reader(open(siteFile, 'r'))
    for row in reader:
        hour = row[0].split(' ')[1].split(':')[0] #get the hour from the row

        #Add the data point for that hour to the dictionary
        if hour not in hours:
            list = [float(row[1])]
            hours[hour] = (1,float(row[1]),list)
        else:
            count,sums,hourList = hours[hour]
            hourList.append(float(row[1]))
            hours[hour] = (count+1,sums+float(row[1]),hourList)

    #Loop through each hour in the dictionary and calculate the average for the hour
    for hour in hours.keys():
        if hour not in averages:
            count,sums,hourList = hours[hour]
            hourList = sorted(hourList)
```

```
            length = len(hourList)
            l50[hour] = hourList[length/2]
            l90[hour] = hourList[length-int(length * .9)]
            averages[hour] = sums/count
    count = 0
    for key in sorted(averages.iterkeys()):
        print "%s: Leq: %s, L50: %s, L90: %s"  % (count,averages[key],l50[key],l90[key])
        count +=1
    return averages,l50,l90

#calculate the overall averages of Leq, L50, and L90
def overallAverages(siteFile):
    hourlyAvgs,l50,l90 = averageHourly(siteFile)
    Leq = sum(hourlyAvgs.values())/24
    L50,L90 = nthPercent(siteFile)
    print "Leq: %s, L50: %s, L90: %s" % (Leq,L50,L90)
    return Leq,L50,L90

#calculate the averages, splitting the data into day and night
def dayNightAverages(siteFile):
    reader = csv.reader(open(siteFile,'r'))
    dayData = []
    nightData = []
    for row in reader:
        hour = row[0].split(' ')[1].split(':')[0]
        print hour
        if (7 <= int(hour)) and (int(hour) < 19):
            dayData.append(float(row[1]))
        else:
            nightData.append(float(row[1]))

    dayLen = len(dayData)
    nightLen = len(nightData)

    print dayLen, nightLen

    orderedDay = sorted(dayData)
    orderedNight = sorted(nightData)

    dLeq = sum(dayData)/len(dayData)
    nLeq = sum(nightData)/len(nightData)
```

```
    dL50 = orderedDay[dayLen/2]
    nL50 = orderedNight[nightLen/2]

    dL90 = orderedDay[dayLen-int(dayLen * .9)]
    nL90 = orderedNight[nightLen-int(nightLen * .9)]

    print 'Daytime: Leq= %s, L50=%s, L90=%s' % (dLeq,dL50,dL90)
    print 'NightTime: Leq= %s, L50=%s, L90=%s' % (nLeq,nL50,nL90)
    return (dLeq,dL50,dL90),(nLeq,nL50,nL90)

#Averages all of the frequency columns from an 'All_3rd' file.
#
#WARNING: THIS IS AN INCREDIBLY SLOW AND COSTLY PROCCESS AND HAS NOT BEEN FULLY TESTED.
#         SPREADSHEET PROGRAMS LIKE EXCEL ARE RECOMMENDED TO AVERAGE THE FREQUENCY COLUMNS
#         MUCH FASTER
def averageFrequencies(siteFile):
    frequencies =
[12.5,16.0,20.0,25.0,31.5,40.0,50.0,63.0,80.0,100.0,125.0,160.0,200.0,250.0,315.0,400.0,500.0,630.0,800.0,1
000.0,1250.0,1600.0,2000.0,2500.0,3150.0,4000.0,5000.0,6300.0,8000.0,10000.0,12500.0,16000.0,20000.0]
    decibels = []
    reader = csv.reader(open(siteFile,'r'))

    count = 0
    print 'done'
    for row in reader:
#         print row
        for i in range(len(frequencies)):
            if len(decibels) > i:
                decibels[i] += row[i+1]
            else:
                decibels.append(row[i+1])
        count +=1

    for i in range(len(decibels)):
        print '%s: %s' %(frequencies[i],decibels[i]/count)

    return (frequencies,decibels/count)
```

Appendix F: Annotated Intrusive Sound Graphs

In this appendix graphs with specific manmade sounds that the team found to be intrusive upon the natural soundscape of each site are shown. These sounds were determined by going out onto site and making observation logs. After the data was collected, the observation logs were cross-referenced with the decibel readings. It should be noted that the chosen sounds were not the only intrusive sounds observed. They were, rather, a few of the many that were arguably the most conclusive. Each graph is titled with the site, followed by the units used, and lastly the date and time the sound was heard. Below each graph is a caption that says what the sound is.

D.1: Cadillac Mountain

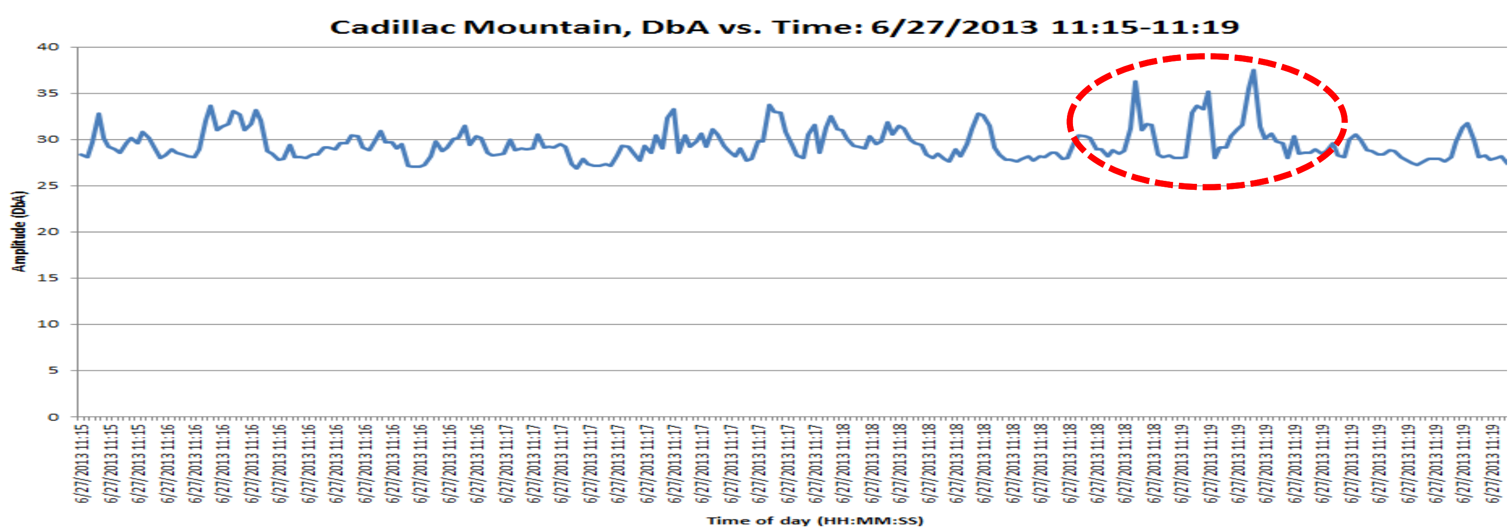


Figure 36: Car Alarm

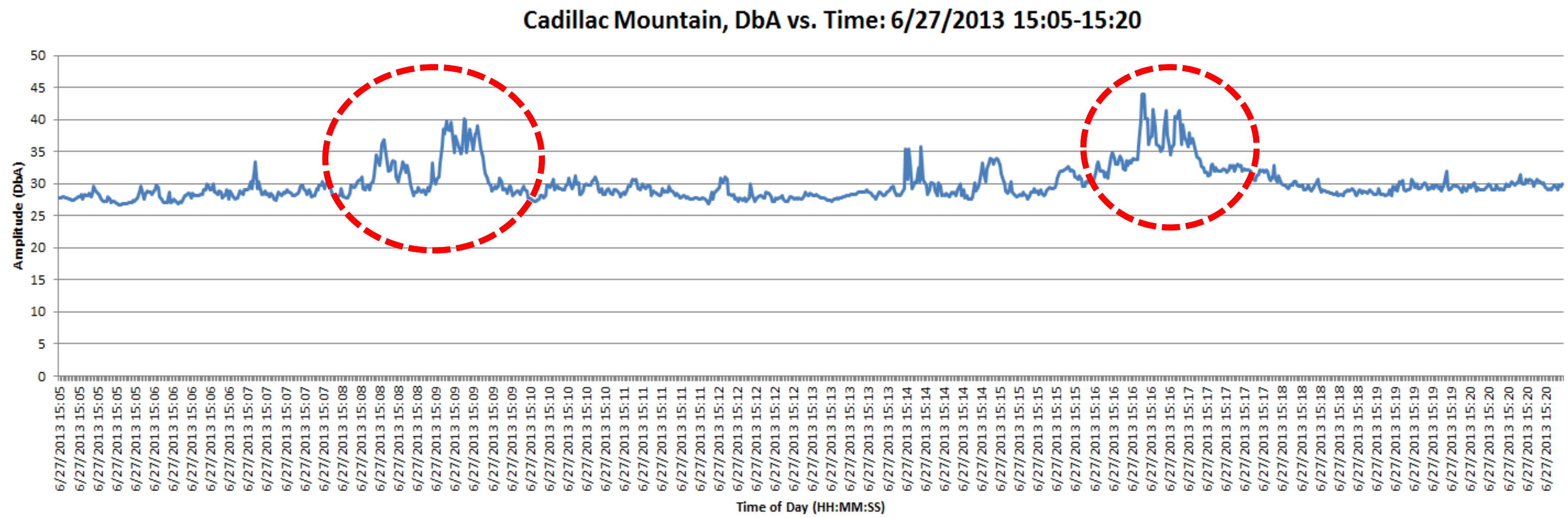


Figure 37: Motorcycles

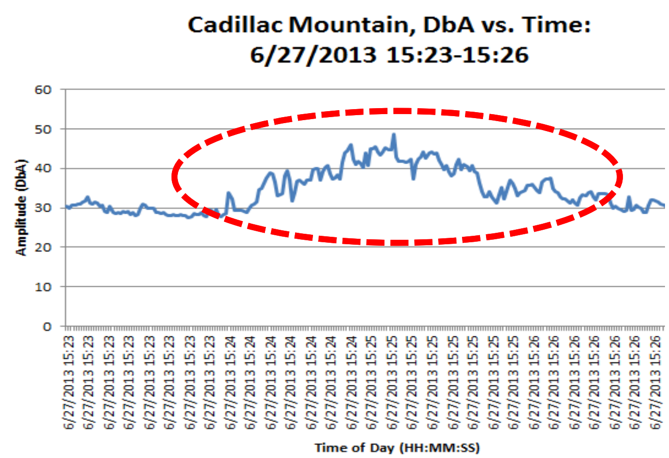


Figure 38: Airplane

D.2: Pine Hill

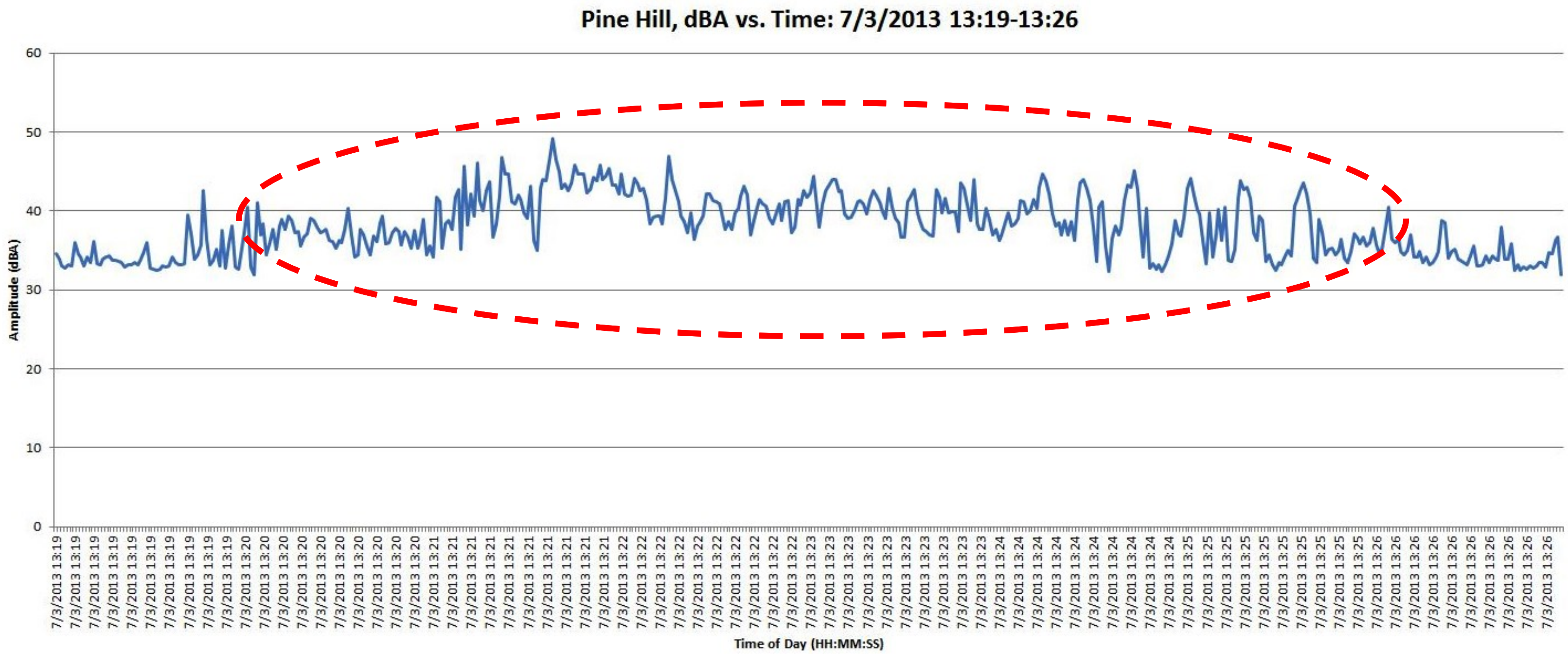


Figure 39: Airplane

D.3 Northeast Creek

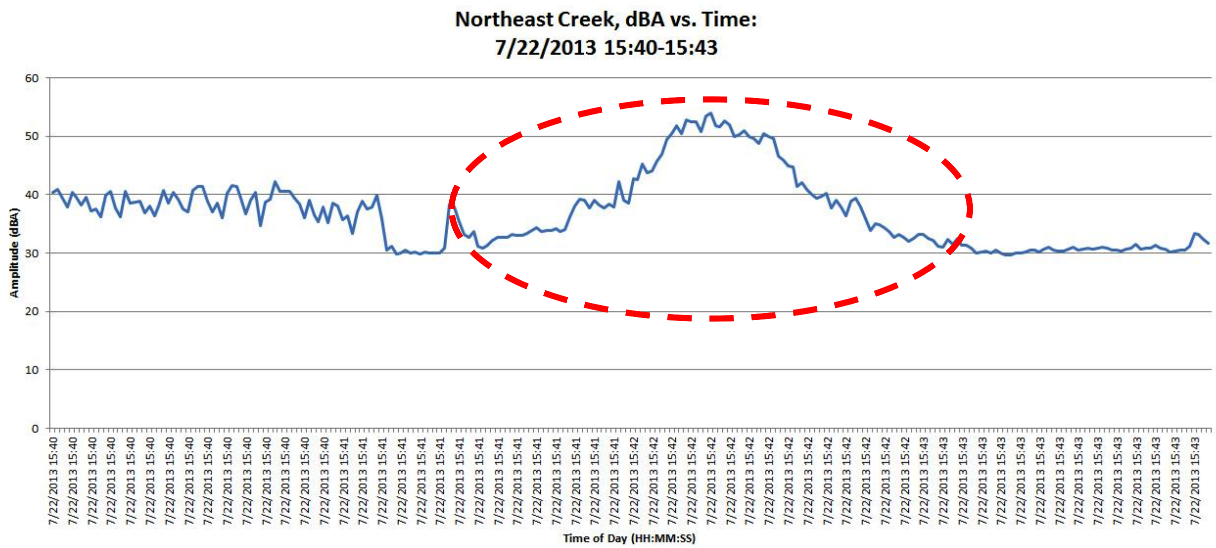


Figure 40: Airplane 1 at Northeast Creek

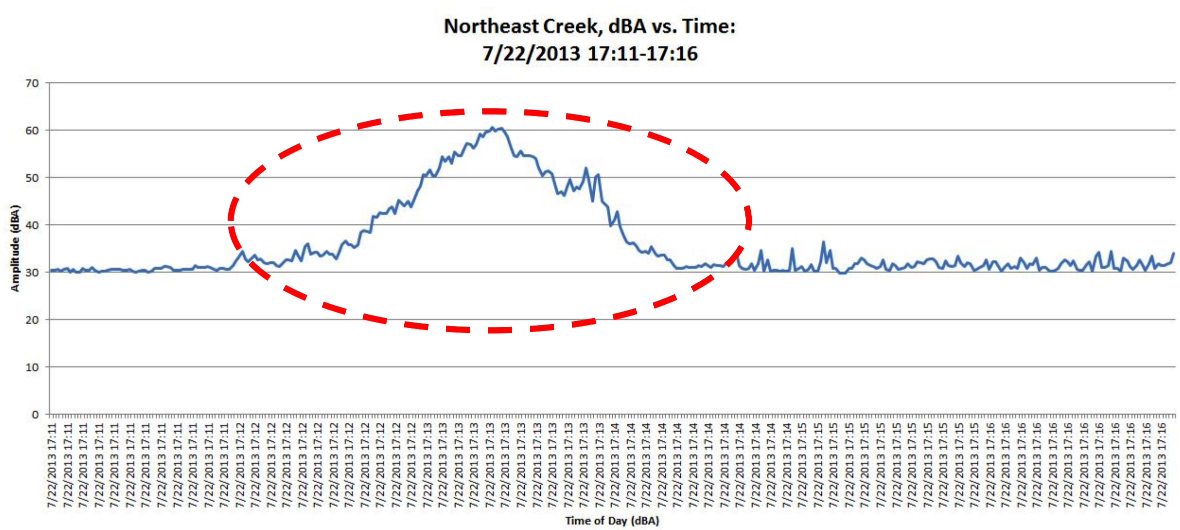


Figure 41: Airplane 2 at Northeast Creek

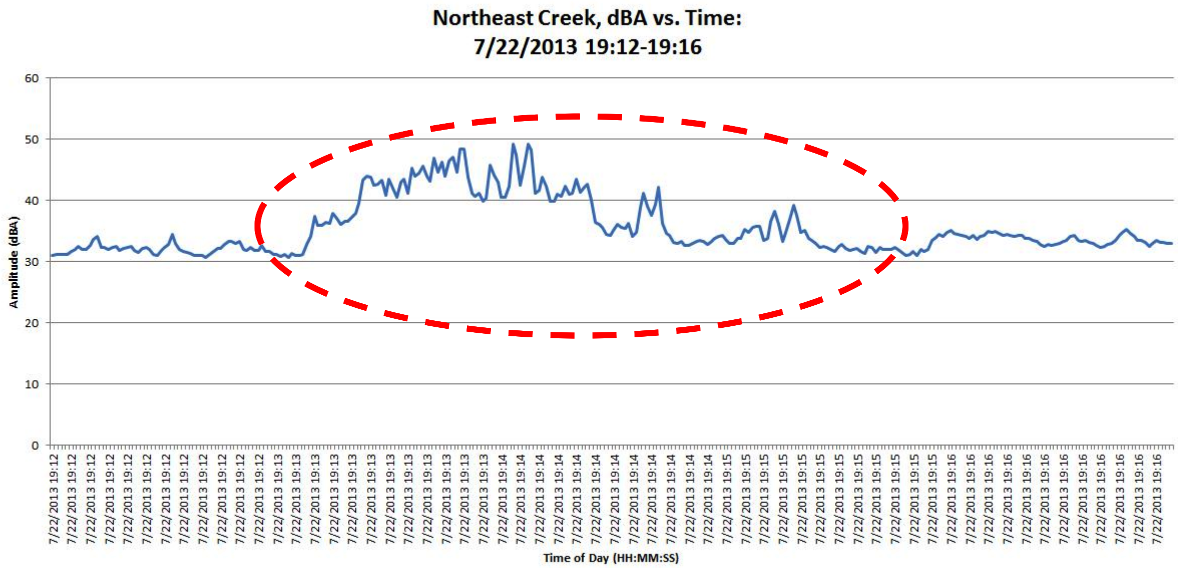


Figure 42: Airplane 3 at Northeast Creek

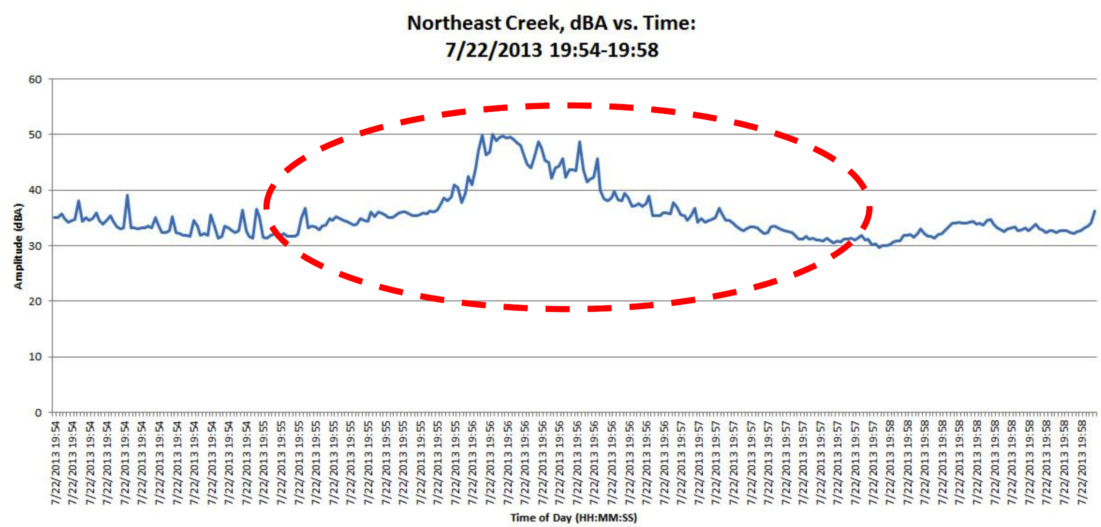


Figure 43: Airplane 4 at Northeast Creek

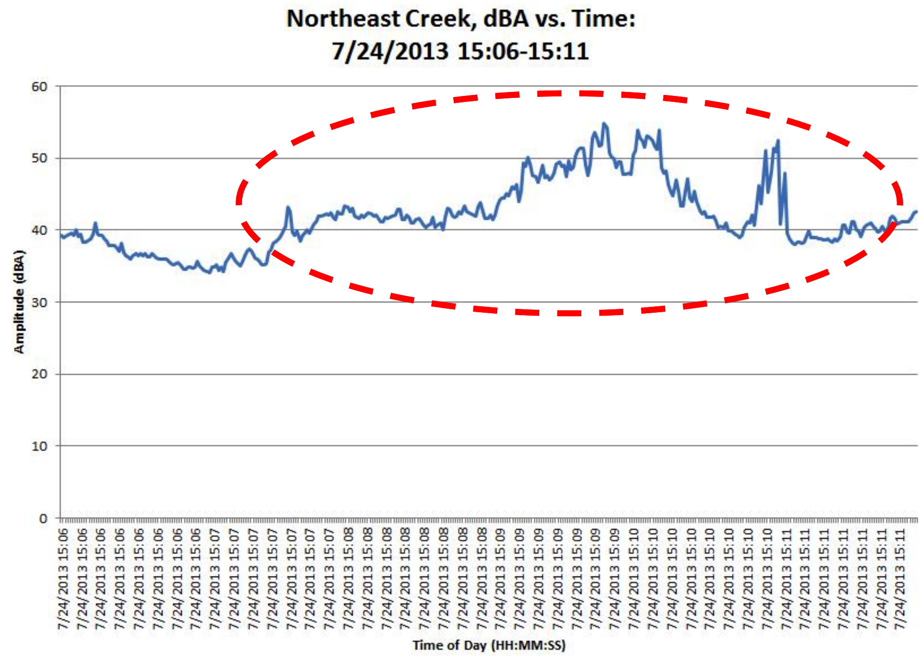


Figure 44: Airplane 5 at Northeast Creek

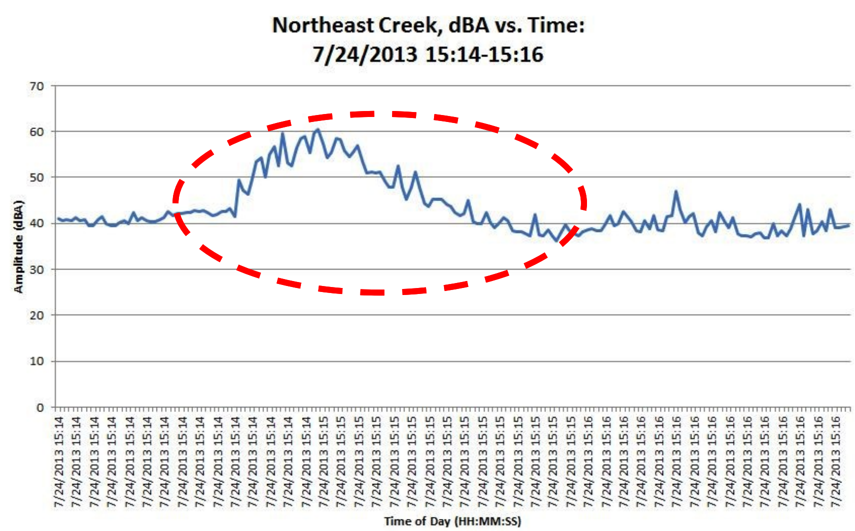


Figure 45: Airplane 6 at Northeast Creek

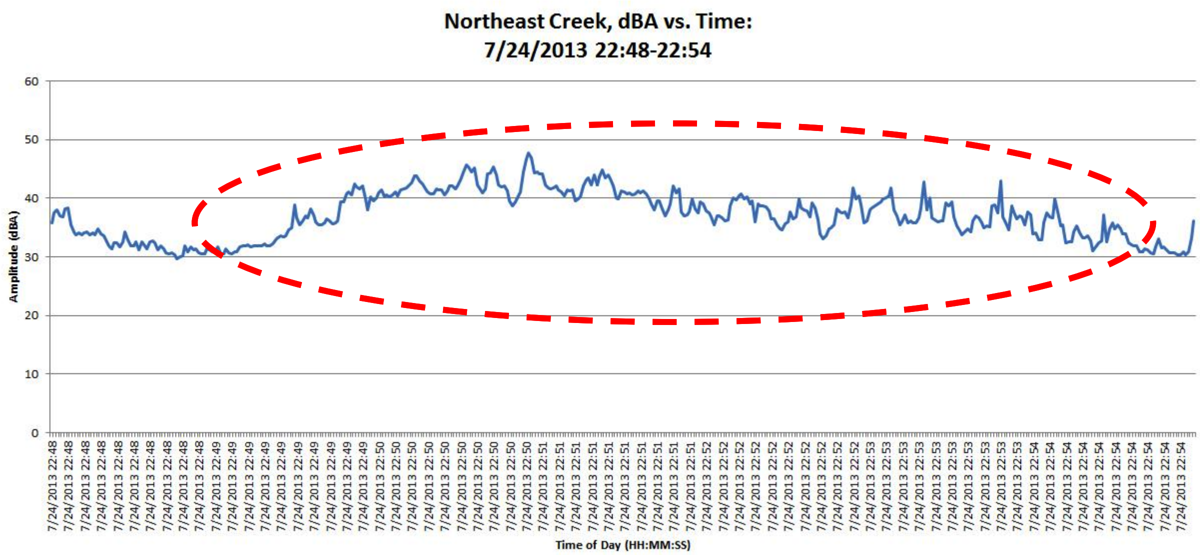


Figure 46: Airplane 7 at Northeast Creek

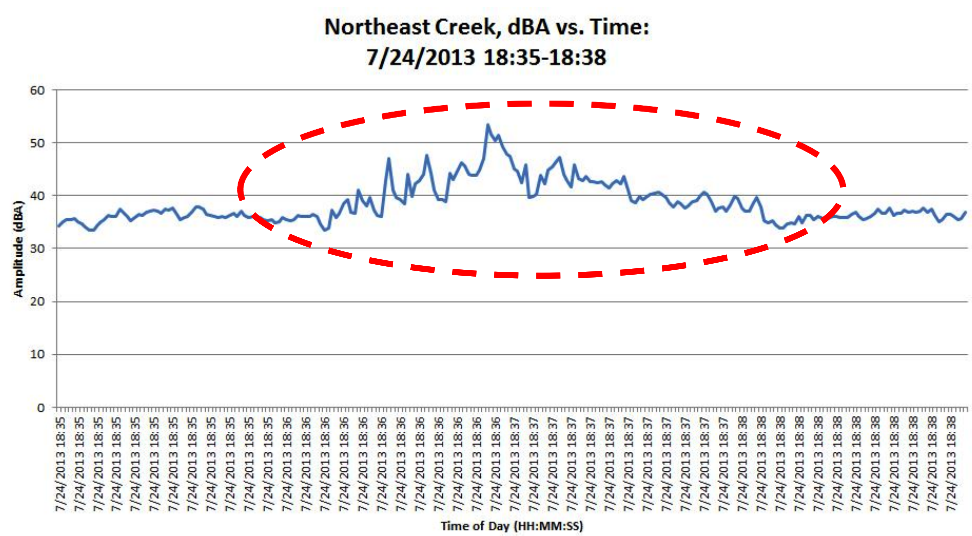


Figure 47: Airplane 8 at Northeast Creek

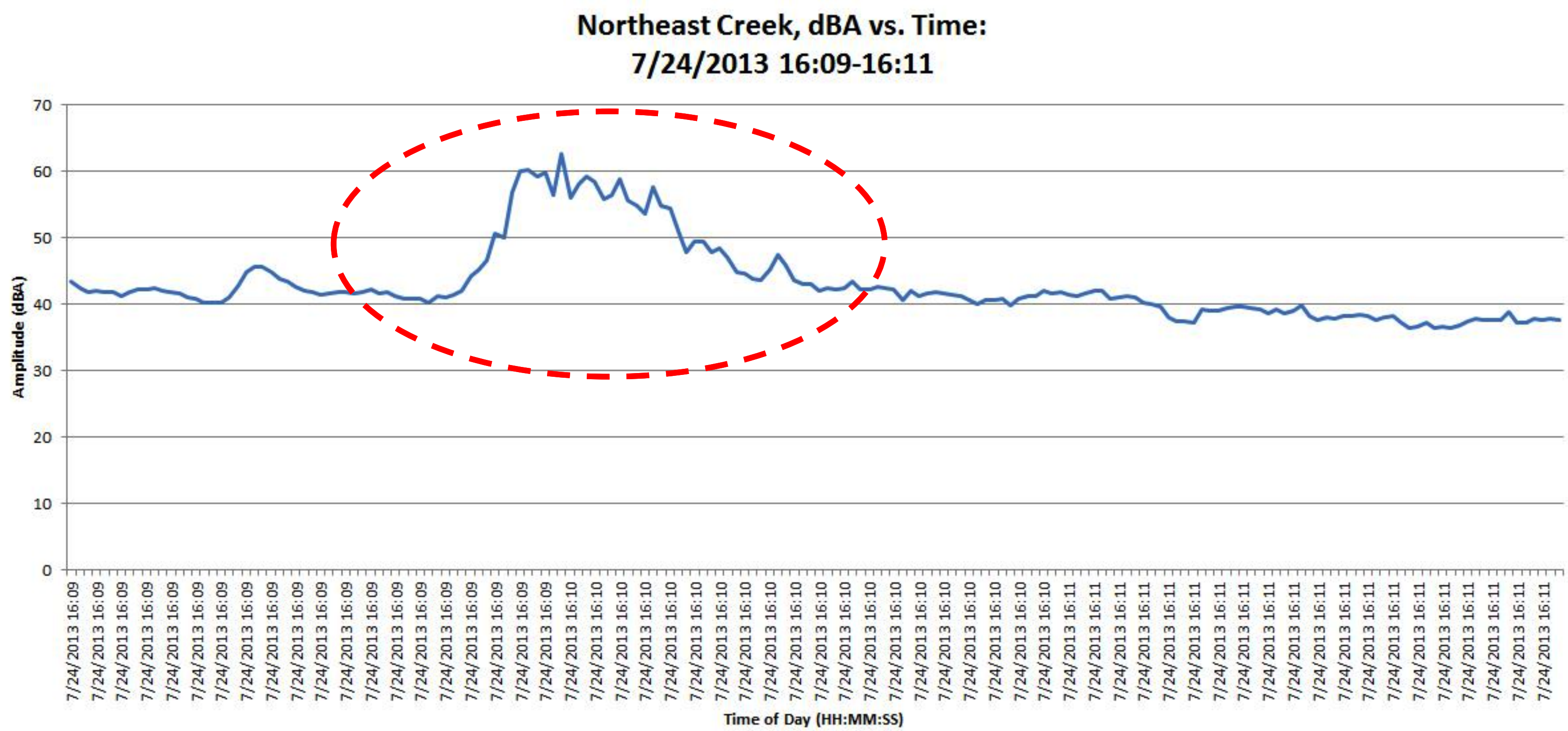


Figure 48: Airplane 9 at Northeast Creek

Appendix G: 1/3 Octave Band Graphs

This appendix contains all of the 1/3 octave band frequency profiles obtained for each site. The x – axis is labeled with the individual frequency ranges, and the y – axis is labeled with decibels (dBA). These frequency levels are the overall averaged levels for each seven-day period.

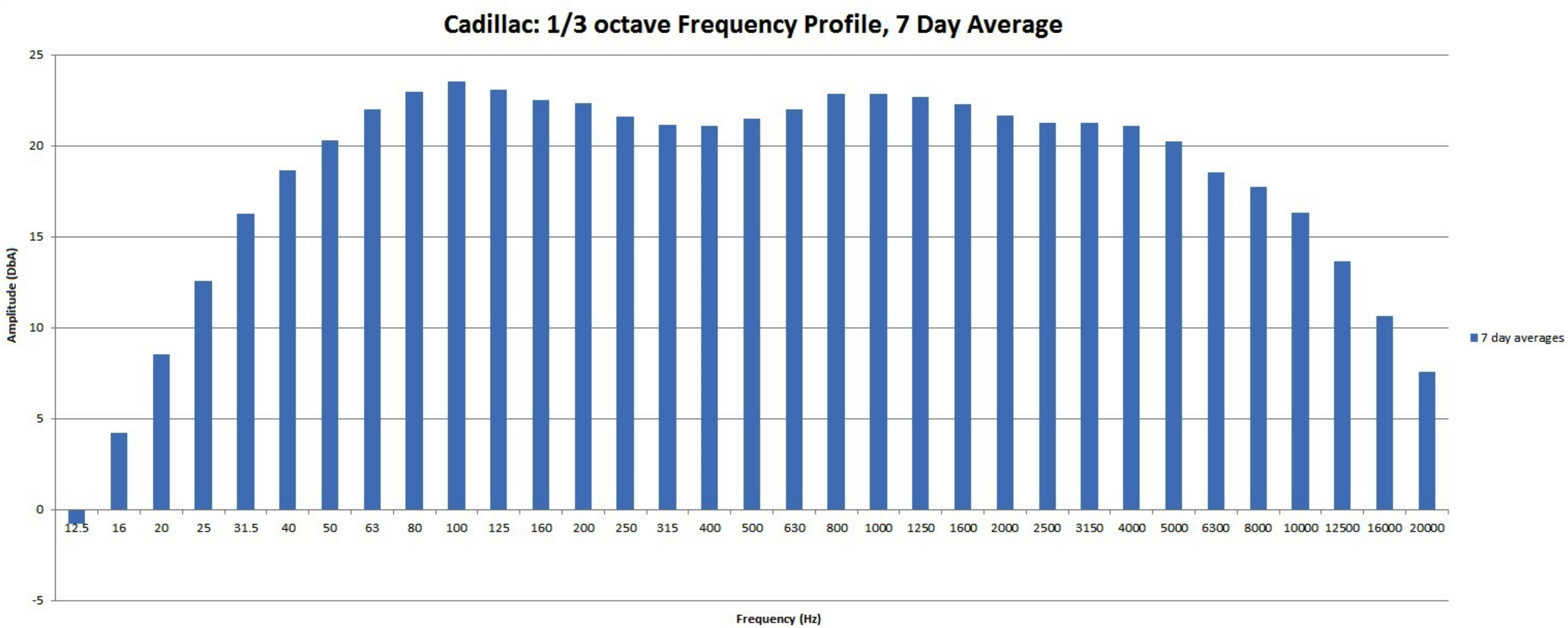


Figure 49: Cadillac 1/3 Octave Band Frequency Profile

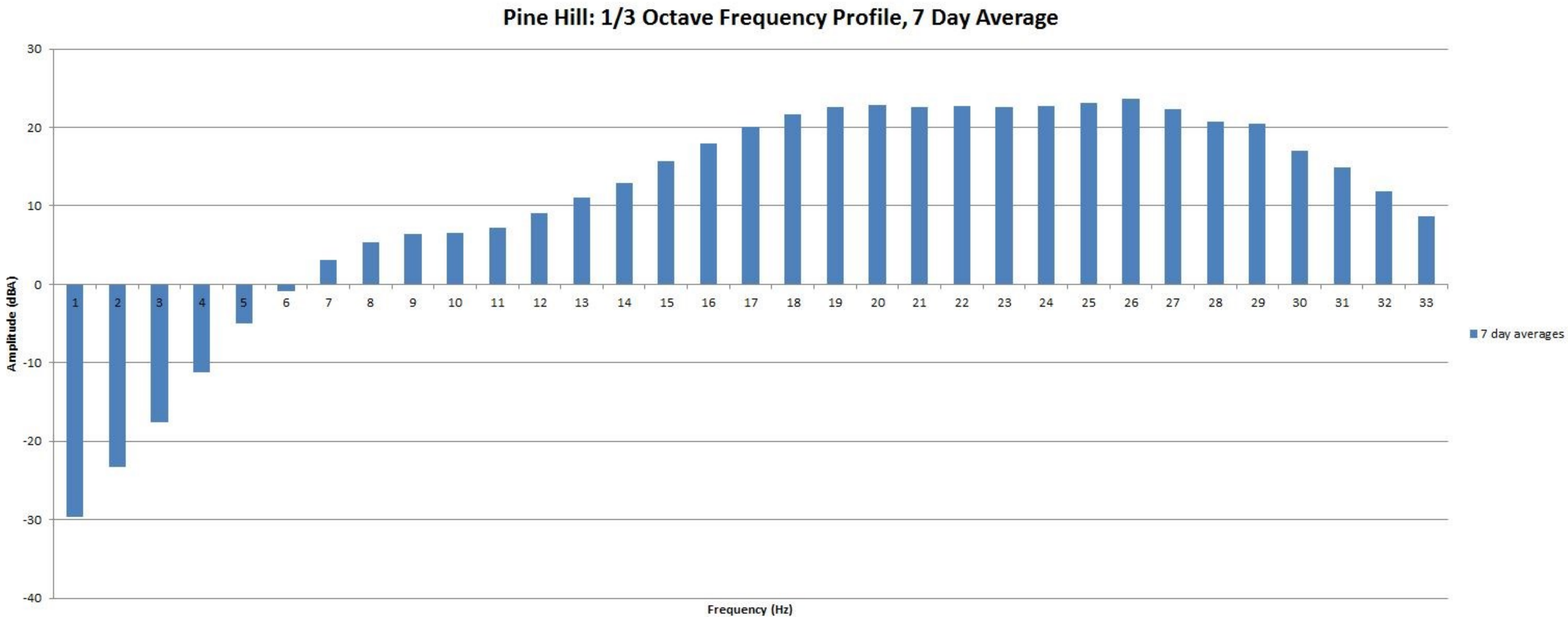


Figure 50: Pine Hill 1/3 Octave Band Frequency Profile

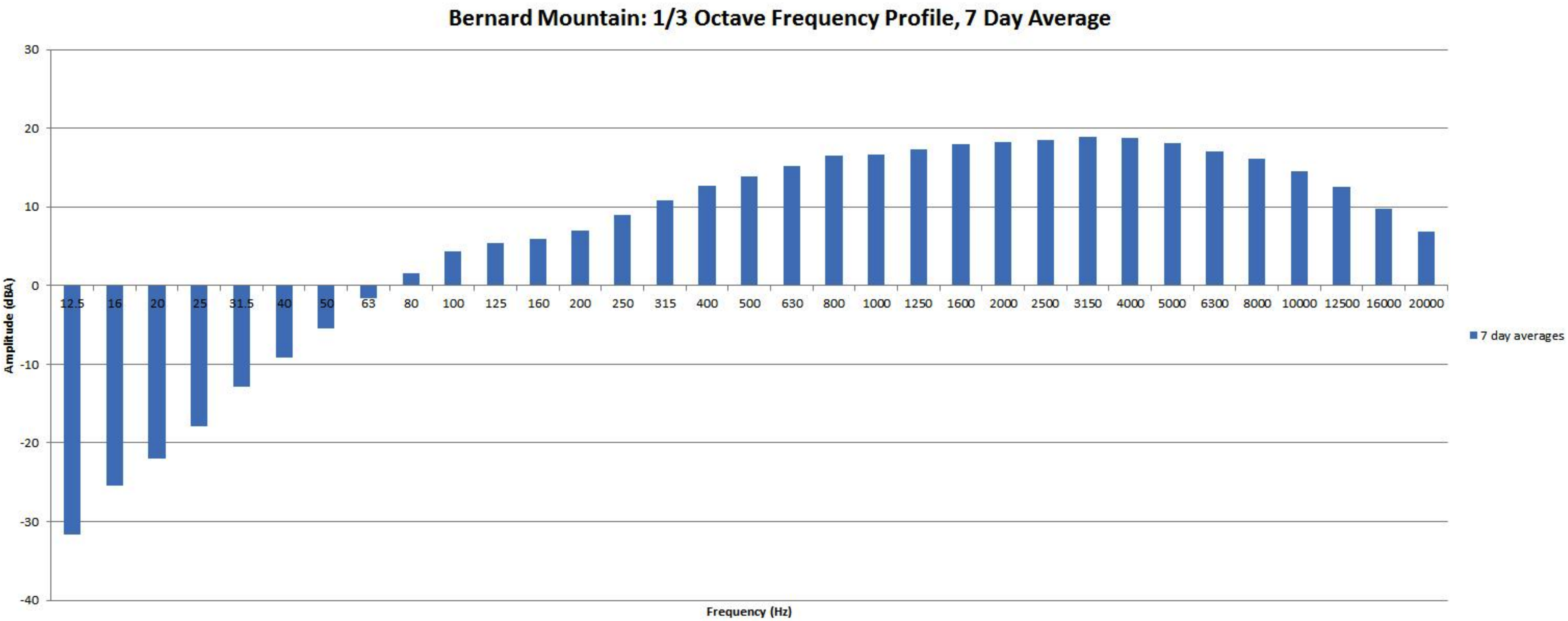


Figure 51: Bernard Mountain 1/3 Octave Band Frequency Profile

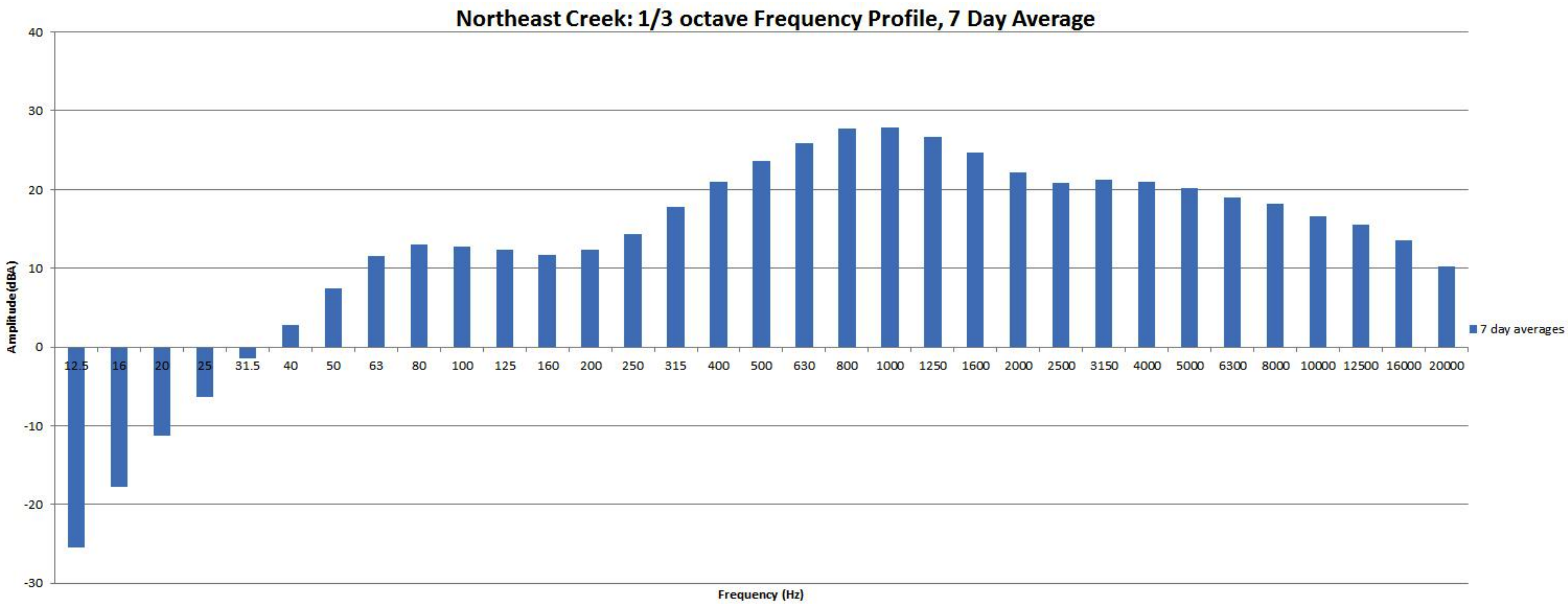


Figure 52: Northeast Creek 1/3 Octave Band Frequency Profile

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